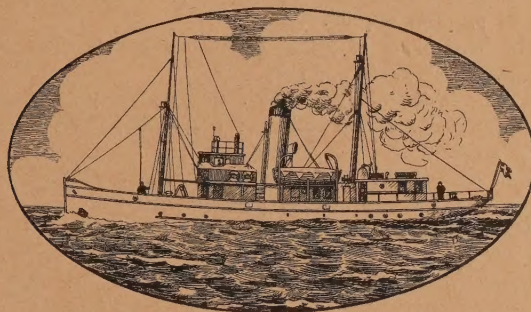


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Report
of
The Danish Biological Station
to
The Ministry of Shipping and Fisheries



XL

1935.

By

H. Blegvad, Ph. D.
Director

Copenhagen. C. A. Reitzel.
1935.

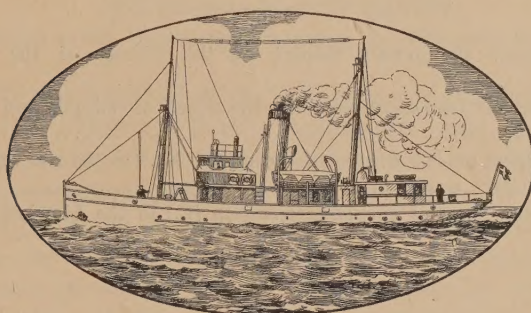
The Reports from the Danish Biological Station (Nos. I—XXI) are published in the official Danish "Fiskeri-Beretning" for the years 1890—91 until 1912. After this year they appear as special publications. The Reports I—XXXII are edited by the late Dr. C. G. Joh. Petersen, the Reports XXXIII—XXXVI by Dr. A. C. Johansen and the later Reports by Dr. H. Blegvad.

- I. *C. G. Joh. Petersen*: Fiskenes biologiske Forhold i Holbæk Fjord. (1890—91)* 63 pp. 1 Chart. Out of print.
- II. *Idem*: On the Eggs and Breeding of our Gobiidæ. (1891—92.) 9 pp. Two Plates. Out of print.
- III. *Idem*: The Pelagic Life in Færev Sound etc. (1892—93.) 38 pp. Tables. Out of print.
- IV. *Idem*: On the Biology of our Flat-fishes and on the decrease of our Flat-fish Fisheries. (1893—94.) 146 pp. 2 Plates. 1 Chart. Many Tables. Out of print.
- V. *Idem*: The common Eel (*Anguilla vulgaris* T.) gets a Particular Breeding-dress before its Emigration to the Sea. (1894—95.) 35 pp. With 2 Plates. Etc. 64 pp. Out of print.
- VI. *Idem*: The Yearly Immigration of young Plaice into the Limfjord etc. (1895—96.) 48 pp. 1 Chart. 2 Tables. Out of print.
- VII. *Idem*: Plankton-Studies in the Limfjord. 1897. 23 pp. 1 Map. 4 Tables. Out of print.
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- XIII. *A. Otterstrøm*: Eggs and Young of Fishes in the Danish Waters. (Investigations during 1904 and earlier years.) 1903 and 1904. 85 pp.
- XIV. I. *C. G. Joh. Petersen*: The Influence of Light on the Migrations of the Eel. II. *K. I. Gemzøe*: Age and Rate of Growth of the Eel. 1906. 39 pp.
- XV. *Idem*: I. First Report on the Oysters and Oyster Fisheries in the Lim Fjord. (70 pp.) 1908.
- XVI. *C. H. Ostenfeld*: On the Ecology and Distribution of the Grass Wrack (*Zostera marina*) in Danish Waters. With 9 figures. 1908. 62 pp.
- XVII. *C. G. Joh. Petersen*: II. Second Report on the Oyster and Oyster Fisheries in the Lim Fjord. 1908. (24 pp).
- XVIII. *C. G. Joh. Petersen*: I. The Yield of the Limfjord fisheries in recent years and the transplantation of Plaice in 1908. With 6 tables and 1 Chart. II. Biological investigations on the stock of Plaice in the Limfjord. With 3 Tables. III. The Yield of the Prawn fishery from 1885—1907 and its improvement by means of protection. With 3 Tables. 25 pp. 1909.
- XIX. *Idem*: Some Experiments on the Possibility of combating the harmful Animals of the Fisheries, especially the Whelks in the Limfjord. 20 pp. 1911.
- XX. *C. G. Joh. Petersen* og *P. Boysen Jensen*: Valuation of the Sea. I. Animal Life of the Sea-Bottom, its food and quantity. With 6 Tables, 3 Charts and 6 Plates. 81 pp. 1911.

*) The figures in () refer to the "Fiskeri-Beretning" for the years quoted.

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Preliminary Report on the Disease of the Eelgrass (*Zostera marina* L.)

By

HENNING E. PETERSEN

D. Sc., Lecturer at the Botanical Laboratory of the University of Copenhagen.

At the end of August 1933 the Director of the Danish Biological Station, H. Blegvad, D. Sc., invited the present author as a botanist to assist the said institution in the investigations that had been planned by Dr. Blegvad and the purpose of which was to throw light on the disease that has appeared in the eelgrass (*Zostera marina* L.) of the Danish waters during recent times. Being at the time busily engaged in the study of this very disease I most gladly accepted the invitation, for which I render my best thanks to Dr. Blegvad.

From thenceforward the Danish Biological Station has provided me with eelgrass samples from various parts of our waters. These samples have essentially added to my own material, which I collected myself at Frederikshavn during studies at the Marine-Biological Laboratory of the University, or which was sent to me by Henry Nielsen, the fisherman of the Laboratory.

Referring to the report of Dr. Blegvad as regards the history of the disease I shall in the following give a survey of my results and on the whole report on such knowledge of the cause of disease as has been acquired by foreign investigators.

As will be known the disease appears as a wasting of tissue partly in the rhizomes, partly in the leaves and the flowering stems; according to my investigations the roots escape, and even severely affected plants seem to be able to flower and to set.

Especially in the leaves the disease is most conspicuous: at first brownish or greyish spots appear, often of a characteristic shape (see Fig. 1); later on

these spots turn dark-brown or black, and they may spread all over the leaf until they have nearly superseded the original green colour. When this stage of disease is reached the leaves usually fall off. They sink to the bottom where they can infect the plants by contact, or they are sooner or later carried away by the current, being thus able to infect the neighbouring vegetations.

The disease checks or stops the assimilation, the power of forming organic matter by means of the light, so that the power of putting out new shoots is reduced or completely done away with. The colour of the diseased rhizomes, does not differ very much from that of the older normal rhizomes. The spots and the confluent dark parts of the flowering shoots often have a cleaner brown or blackish-brown colour than the spots of the leaves.

This disease seems to have spread very rapidly along the coasts of the Atlantic. It was first observed at the end of 1931 on the coast of Virginia whence it has spread all up to Nova Scotia; in 1932 it was met with on the coasts of Europe, and in all places of its occurrence it has caused an enormous mortality of the eelgrass, so that in former localities of fresh and green vegetations we now only find poor black remains. In Danish waters it was



Fig. 1.
Spotted leaves.

first observed in 1932—33. A salinity of less than 10 ‰ seems to draw the line against its advance, a fact which in our own waters was also verified by Dr. Blegvad.

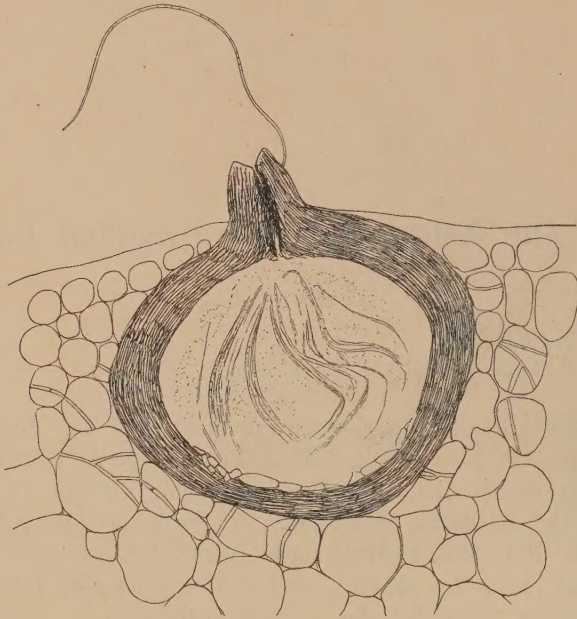


Fig. 2. Longitudinal section of a perithecium.

This rapid spreading of a marine disease justly roused astonishment and fear, and to begin with it was supposed that we had to do with a bacteriosis because a fungoid disease could not be supposed to spread so rapidly.

This supposition seemed to be corroborated by the works of various French investigators (Fischer-Piette, Heim and Lami). From the diseased tissue they isolated a bacterium, which they supposed to be the cause of the disease.

But this hypothesis was not generally accepted, and many other theories saw the light; among other things the disease was taken to be caused by pollution of the water.

During my studies at the Marine Biological Laboratory of the University in July 1933 my attention had been drawn upon the disease, and I had then observed that the mycelium of a fungus was found in all diseased parts of the plant. The presence of such a mycelium had already been established at the Laboratory of Plant Pathology of Ottawa by Dr. E. Silver Dowding "in one section of a blackened portion of the cortex of the rhizome, but as it

could not be found in any other of the samples examined, it was not considered to be a cause of the disease"¹). Later examinations of material provided by the Biological Station established this connexion between mycelium and diseased parts of the eelgrass. On the basis of these facts I went in for the view that the fungus must be the cause of the disease. After a short item in "Nature", Dec. 1933, in which I mentioned this characteristic connexion, I received information from Miss Irene Mounce, Assistant Plant Pathologist, Ottawa, that she, too, had found a fungus in diseased eelgrass. However, an examination of the material sent to me by Miss Mounce did not at once convince me that the fungi were identical. On old leaves Miss Mounce had found some perithecia, in which I could find no spores.

I have several times managed to isolate and cultivate the fungus that is found on diseased eelgrass of this country (on rhizomes of material from Frederikshavn and in rhizomes and leaves from Nyborg). I had then seen that on an artificial substratum it was apt to form perithecium-like bodies. Real perithecia I did not see until June 1934, and without some forming of spores the wide spread of the disease could in no way be accounted for. However, in June 1934 material sent to me by Henry Nielsen, Fisherman of Frederikshavn, enabled me in rhizomes to establish the presence of an enormous quantity of perithecia, each of which formed many spores. (Fig. 2. Fig. 3).

Having made this observation, which was later corroborated by means of material sent to me from the Danish Biological Station at Nyborg, I had no doubt that this fungus must be the cause of the

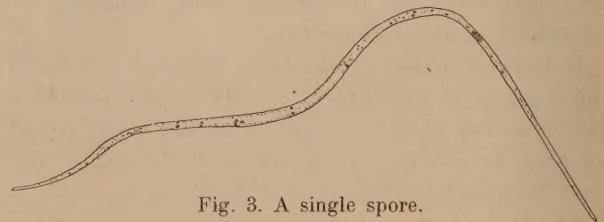


Fig. 3. A single spore.

disease and that the infection was in the first line brought about by the long thin spores being carried from one place to another. A short item in the "Nature" of July 1934 informed of this observation.

¹) HARRISON F. LEWIS: Transact. of the Nineteenth American Game Conference. Washington D.C. 1933, p. 411—423.

My theory was verified by the later investigations of Miss Mounce's published in the *Canadian Journal of Research*, Sep. 1934. No doubt the fungi found by Miss Mounce and by myself are identical. Miss Mounce and W. W. Diehl describe the fungus as *Ophiobolus halinus*. On the other hand Ch. E. Renn, Woods Hole Oceanographic Institution, Mass., has maintained that a protozoon, *Labyrinthula* sp. (which had also been noticed by me to live as a parasite in Danish material) might possibly be the pathogene. He categorically rejects the possibility of the fungus being of any importance. He says ("Nature", September 1934) "Further, we have been unable to observe the *Ophiobolus*-like fungi reported by other investigators as commonly on the rhizomes and leaves of diseased plants". However, in a letter to Mr. Renn I have demonstrated that the material, which he sent to me, contained an abundant quantity of *Ophiobolus*, which fact he has later admitted (by letter).

In "Nature", 13-X-34, T. G. Tutin makes a brief mention of this fungus. According to him it was found in dead eelgrass on "the Atlantic coast of North America, Ireland, Southwest England, Channel-Islands and Denmark". The author is not sure that it is the pathogene, "but it is impossible to make any definite statement at present as to this. Experiments on its pathogenicity are in progress at the Marine biological Association's Laboratory at Plymouth". Since then Miss Clarence Cottam has written an interesting paper: "Past periods of Eelgrass scarcity", *Rhodora*, July 1934, which I am going to comment on at the end of the present paper.

In the following I shall describe the principal features in the biology of this fungus as far as they are known to me at present. In my opinion the remarkable infectiousness of the present disease is due to the said spores, ascospores, which are formed in *perithecia*. In this country the *perithecia* seem to develop principally in the rhizomes; I have not seen *perithecia* in leaves myself, not even in leaves that have been lying in the moist *Zostera* heaps of the shore. As far as I know these spores are the only small particles that are carried from one plant to the other. In the spreading of the disease over vast areas, as for instance the contingent spreading across the Atlantic, these spores, which apparently do not live very long, are hardly of any importance. The carriers of infection are no doubt infected plants

or fragments of plants, which are carried across vast areas of the Sea; on their arrival at new localities spores are developed. Of course it is not out of the question that a vegetative mycelium might grow out of dead leaves arrived and infect the fresh ones. My experiments have established that the mycelium is able to penetrate into leaves. However, in most cases an absolutely fresh *Zostera*-plant is infected by the said spores. According to my experience the forming of *perithecia* begins at the end of winter and continues until late in summer. The spores seem to be most vital during the first part of the period — spores isolated at the end of November in material from Frederikshavn were apparently incapable of germinating, for at this time I tried, with the assistance of Prof. Dr. C. A. Jørgensen of the agricultural and veterinary college, to make a series of one-spore-cultures, but failed in the experiments. The spores are about $\frac{1}{4}$ mm. long but only $\frac{2.3}{1000}$ mm. broad. They are flexible and easily adhere to vegetable bodies. The outer leaves of the shoot and the ends of the leaves are preferentially attacked. The *hyphæ* formed by the spores enter the tissues and gradually spread widely, often transversing the great characteristic air-spaces of the eelgrass leaves. Also the rhizomes and the flowering stems are most probably infected by spores, but here the penetrating is no doubt more difficult on account of the more impregnated outer wall of the *epidermis*. Direct observations seem to indicate that the rhizomes are very frequently infected by a mycelium, which from the diseased leaves grow down into the root-stocks through bases (the sheaths) of the leaves. The first infection of the leaves appears as grey or greyish-brown spots. Coincidentally with the spreading of the infection inside the leaves the spots become more distinct — they often stand off conspicuously with characteristic acute angles — and assume a darker brown colour. Later on the spots may be merged within large parts of the leaf, and at last the leaf will turn quite black or blackish-brown. Then it is often thrown off and may be carried to other places, so that other individuals are exposed to contagion. The rhizomes attacked are generally old ones, at least 1 year old, and to look at they are not very different from normal root-stocks.

The penetrating mycelium, the *hyphæ* (Fig. 4), destroy the cells in the tissue of the leaves. The diseased cells are put out of action, and, in the case of the chlorophyllous cells, the assimilation of

the carbonic acid of the water stops, so that the forming in the plant of organic nourishment ceases. As mentioned above the diseased plants assimilate less than the sound ones, and the consequence is an impairment of their power of storing nourishment in the rhizomes for a later development of shoots. Late in autumn the attack seems to come to a stand, but the growth of the fungus may continue next year. The new leaves formed towards the end of the winter period are often fresh in their first stages.

But after the winter period the attack begins again, leaves and rhizomes are infected, so that the forming of nourishment is but small. Vigorous

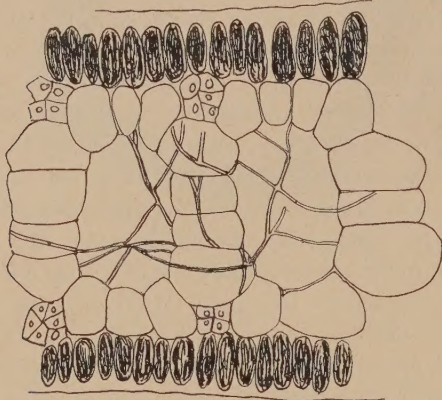


Fig. 4. Mycelium in the mesophyll of a *Zostera*-leaf.

plants often have some aliment left in their rhizomes, by means of which they may keep alive. But if the attack is continued, the plants will always end in being destroyed. The bottom, in which vigorous vegetations of eelgrass were growing, is now full of decaying and fetid remains.

In the summer of 1934 I had the opportunity of observing such decimated vegetations of eel-grass in the water off Frederikshavn. Strange to see a great part of the remaining individuals were fructiferous plants. The fructification seemed to take place unimpededly and the ripening to be normal. Evidently these plants were very vigorous individuals with so much food in reserve, that they were able to carry through a fructification in spite of the reduced assimilation. Besides these individuals I found some few vegetative specimens. As mentioned the higher power of resistance in some individuals may be due to a greater reserve of food, or it may be

ascribed to an immunity of these plants. Even though they are affected by the disease, the attack is not a radical one: some green tissue is always left for the assimilation. When this period of disease is over, we shall no doubt in most places find some individuals left, which are able to regenerate the stock.

In our southern waters the low salinity seems to check the attack, and here the stock will hardly suffer severely under the disease.

In using appropriate disinfectants e. g. 1‰ corrosive sublimate, bacteria and other organisms on the surface of the leaves and the rhizomes may be killed. Thus we can get the pure mycelium to grow out on an alimentary substratum on which these organs are placed. For this purpose should be used a decoction of *Zostera*, boiled in salt water and mixed up with agar-agar. On this substratum the fungus will grow as a greyish, later on rusty red mycelium with a marked tendency of developing perithecia.

No other spores than the said ascospores were observed to be formed.

According to my observations there are symptoms of different races of fungi affecting the *Zostera*; however, closer investigations on this hypothesis will be made later on.

In the following I shall give a survey of the material which was put at my disposal by the Danish Biological Station, and append observations occasioned by this material. When not commented on the leaves were of the normal average breadth.

1. Nakskov Fjord, October 1933. Drifting eelgrass; mycelium was found in one leaf.
2. *ibid.* October 1933. Mostly growing plants, unaffected material; some few drifting leaves attacked.
3. *ibid.* October 1933. Growing plants with fresh and dead leaves; some of the latter had been affected.
4. *ibid.* November 13th, 1934. Langø, Kappel (Julius Juul, Fisherman). Some leaves affected.
5. 0.5 naut. mile W. of the harbour of Karrebæksminde; 1.5 m.; September 1933. Narrow-leaved variation; fresh material, unaffected.
6. Coast of Vejlø near Dragsbjærg. Depth 1—2 m. No attacks at all.
7. 1 naut. mile NW. of Knudshoved Reef, September 1933. Unaffected, dead eelgrass.

8. Between Vejle and Rosmersholm, September 1933. Eelgrass, soft bottom. Fresh material, possibly with sporadic attacks.
9. Svendborg Sund, October 1933. Dr. Blegvad.
 - a. Dead eelgrass, depth $\frac{3}{4}$ m. Some attacks observed.
 - b. Depth $\frac{3}{4}$ m. Short fresh eelgrass; outer leaves of fresh shoots affected.
 - c. Depth $1\frac{1}{2}$ m. High, broad-leaved eelgrass. Dead, detached leaves and outer leaves of fresh shoots rather frequently affected.
10. Svendborg Sund, August 17th, 1934. Narrow-leaved and broad-leaved forms attacked by fungus in leaves but not in rhizomes.
11. Nyborg Fjord at the anchoring place of the Biol. Station; October 1933. Attacks not infrequent in detached material without rhizomes.
12. Nyborg Fjord off Kalkovnskoven; October 1933. Mostly brown, dead eelgrass; only few leaves affected.
13. Nyborg Fjord off Slipshavn, October 1933. Mainly brown, dead eelgrass without symptoms of the disease; only a few blackish leaves affected.
14. Nyborg, January 1934. Well-grown material with fresh shoots; fungic spots were found on many leaves.
15. Nyborg, February 10th, 1934. Two forms of eelgrass, the narrow-leaved one unaffected. Both leaves and rhizomes of the broad-leaved form had been attacked. The fungus of the rhizomes was isolated.
16. Nyborg, April 1934. Two forms of eelgrass. Narrow-leaved form nearly unaffected; symptoms on a few broad-leaved individuals.
The broad-leaved form is highly debilitated, and it is difficult to localize the fungus; the dark colour of the leaves is partly due to the debility and has not been caused by the disease. It should be noticed that eelgrass leaves dying on account of age or general debility turn dark, but these leaves are mostly of a cleaner brown colour than the diseased ones.
17. Nyborg, May 8th, 1934. Narrow-leaved form. Of this material only the one-year-old leaves had been attacked, the younger leaves hardly showing any symptoms of the disease. However, many rhizomes had been attacked.
18. Nyborg, May 12th, 1934. Drifting eelgrass from the Nyborg Fjord; attacks very insignificant.
19. Nyborg, near the pier of the Station, May 12th, 1934. Mainly narrow-leaved form with insignificant attacks of the leaves and unaffected rhizomes.
20. Nyborg Fjord at Slipshavn, May 12th, 1934. Taken in the dredge on soft bottom. Broad-leaved form with many fresh and unaffected plants. Old rhizomes and leaves showed advanced attacks.
21. Nyborg Fjord, May 29th, 1934. Fresh eelgrass of the normal type with unaffected leaves; in old rhizomes attacks were observed.
22. Nyborg Fjord, October 27th, 1934. Mostly narrow-leaved individuals highly affected; very few fresh leaves and shoots, but no perithecia observed in the few rhizomes of the material forwarded.
23. Kalundborg Fjord, July 21st, 1934; S/S "Biologen". Very broad-leaved eelgrass, the leaves of which had been attacked by the disease; rhizomes unaffected.
24. Vejle Fjord, August 13th, 1934; S/S "Biologen". Broad and narrow-leaved individuals with fungus in leaves and rhizomes. Perithecia were observed in the fragment of a rhizome.
25. The coast off Eltham, the Sound, November 8th, 1934. Mainly narrow leaves slightly attacked; some few broad ones with advanced attacks; no perithecia in the few rhizomes.
26. Kyholm Samsø, July 20th, 1934; S/S "Biologen". Very narrow-leaved eelgrass with diseased leaves; old rhizomes not present.
27. S. of the harbour of Rungsted, September 11th, 1933.
 - a. Depth 0.5 m. Narrow-leaved eelgrass. No attacks in growing plants, some few detached leaves affected.
 - b. Depth 1.5 m. Traces of an attack.
 - c. Depth 4 m. Dead eelgrass with many algæ; no attacks.
28. Nivaabugten, depth 1.5 m. October 6th, 1933. Principally fresh eelgrass; a few detached leaves and flowering shoots, part of which had been attacked.
29. S. of Sletten, September 11th, 1933.
 - a. Depth 1.5 m. No attacks observed.
 - b. Depth 1.5 m. Fungus observed in fructiferous shoot.
 - c. Depth 4.5 m. No attacks observed.
30. Lemvig, September 19th, 1933. S/S "Biologen". Dr. Poulsen. Abundance of completely fresh plants. Attacks observed in a few cases.

31. Agerø, SE. of Lemvig, May 29th, 1934. S/S "Biologen". Dr. Jensen. Old leaves and rhizomes diseased; youngest leaves unaffected.

It appears from this survey that in certain southern areas and certain localities of the Sound no attacks, or at any rate only slight attacks were observed at the time when the material was collected.

From Nyborg numerous samples were forwarded to me, in most cases with diseased material, the attacks, however, exhibiting a highly varying intensity. Presumably this fact is a consequence of the changing currents of this locality. During a long period of northgoing currents the conditions of the spreading of the fungus will be less favourable than during periods when salter water flows in from the north.

When the samples are taken during the spring months, we often find fresh shoots with unaffected young leaves, but no doubt further investigations will show that absolutely fresh leaves put out in highly diseased vegetations are but exceptions, and in these places the plants are no more able to produce normal shoots. In some cases the narrow-leaved forms are found to be attacked, in others not. The material in hand is insufficient for conclusions as to this problem. Our knowledge of the eelgrass forms and their variations is still imperfect. In some cases the narrow-leaved individuals

are no doubt genotypically different from the broad-leaved ones, in other cases they must undoubtedly be considered to be phenotypical variations of the broad-leaved forms.

I shall conclude by mentioning a paper by Miss Clarence Cottam, published in the *Rhodora* of July 1934, called "Past periods of Eelgrass scarcity". In this paper the author mentions that according to evidence in hand the American coasts have on former occasions no doubt met with a marked decrease of the eelgrass quantity.

"From available evidence the eelgrass largely disappeared over the major portion of our Atlantic coast in 1893 and 1894 and it required several years before it had come to normal abundance".

A similar decrease of the quantity is reported to have occurred in 1908.

If these periods of debility have been caused by the same factors as the present one, we may still hope that it is a transient phenomenon: "the fact that there were previous periods of scarcity or limited production of the plant offers some encouragement to the hope that the malady will gradually pass".

Our knowledge of similar epidemic diseases tells us that most likely (1) the virulence of the parasite will gradually abate or (2) the quantity of new immune individuals will increase. In either case there is reason for the belief that sooner or later the *Zostera* vegetation will spread once more.

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Recent Investigations into the Stock of Salmon and Sea Trout in the River Gudenaa.

By

ERIK M. POULSEN

Preface.

The present paper is based principally on fishery statistics concerning the Randers Fjord and the river Gudenaa worked up by the Danish Board of Fisheries and on a material of scales and more special statistic and biological information collected on the initiative of A. C. Johansen, D. sc., late Director of the Danish Biological Station.

A comprehensive material of scales and statistic information was forwarded by Messrs. Kryger & Jensen and M. Schmidt, Fishmongers of Randers. Further Mr. Skaanning, Fishery Official of Randers, has provided information of biological nature together with scales and fish for closer analysis. I beg to render my best thanks to these gentlemen for the material forwarded.

The Gudenaa is the greatest river of Denmark. From its spring NW. of Vejle and down to Randers it is 146 km. long. The inmost part of the Randers Fjord, the narrow course from Randers to Uglehuse, is, however, more like a river than a fjord; the greater part of this distance according to J. P. Jacobsen¹⁾ shows a mean salinity of less than 0.5 ‰ at surface and less than 3 ‰ at bottom. So this narrow part of the Fjord could properly be considered part of the Gudenaa, the total length of which would then be 160 km. But in view of the prevailing notion the division of fjord and river is in the present paper fixed at Randers.

As regards the fisheries the Gudenaa is of special interest in being our only stream inside the Skaw in which the salmon has found satisfactory conditions of breeding and growth. The sea trout having also found good conditions of living in this place, the Gudenaa and the Randers Fjord have throughout the times been an important field of usefulness to the salmon and trout fisheries of this country.

A. C. Johansen and I. Chr. Løfting in 1919¹⁾ gave an exhaustive description of the conditions concerning the stock of salmon and sea trout down to the year 1918 with regard to biology as well as fishery. In this paper it is said of the yield of the salmon and trout fisheries that "the total annual amount caught within the Gudenaa area and the Randers Fjord must at present (in 1918) be put at abt. 3 000 kgs. of salmon and 7 000 kgs. of sea trout." An illustration of the signification of these figures is given by the fact that in the years 1918—21 the annual amounts caught in the Kattegat including the Randers Fjord were abt. 5 000 kgs. of salmon and abt. 14 000 kgs. of sea trout, in other words scarcely twice the quantities of both kinds of fish caught in the Gudenaa and the Randers Fjord exclusively. It is obvious, then, that down to the year 1918 the Gudenaa was of essential importance to the salmon and trout fisheries.

In old times we find a considerable fishing of salmon and sea trout in the Gudenaa. Some few rich

¹⁾ J. P. Jacobsen: Hydrografiske Undersøgelser i Randers Fjord. Randers Fjords Naturhistorie ved A. C. Johansen, 1918.

¹⁾ A. C. Johansen og I. Chr. Løfting: Om Fiskebestanden og Fiskeriet i Gudenaaens nedre Løb og Randers Fjord. With an English Summary. Skr. udg. af Komm. f. Havundersøgelser Nr. 9, 1919.

years (as for instance the year 1820) show catches of nearly 10 000 kgs. of salmon in the numerous salmon weirs at that time situated along the river. During one period in the latter half of the 19th century the catches were considerably lighter. But in the beginning of the 20th century the catches rose once more. At any rate since the middle of the 19th century there was in the Randers Fjord an extensive fishing of salmon and trout with salmon nets, especially during the months of August-November, in other words during a season when considerable numbers of salmon going to spawn entered the river. But neither the intense net fishing in the Fjord nor the equally intense fishing in the very river was able to waste the stock of salmon and trout in the Gudenaa. The complete extinction of the salmon stock of the Gudenaa and the partial wasting of its stock of sea trout were reserved for our own times and brought about by the industrial utilization of the flow of water of this river.

The industrial utilization of the Danish streams shows a constant and strong development since the great war. A number of different industrial establishments have sprung up along our streams, partly in order to use their water-power, partly in order to get rid of discharge water and various kinds of refuse in a cheap and easy way. Both forms of utilization have turned out to be highly injurious to the fish stock. The utilization of the water-power requires the building of weirs, which means an impediment to the up- and downward migrations of the fish, and the setting up of turbines, into which the fish are carried by the current and where they are killed or receive more or less heavy injuries. The eduction of discharge water and refuse in many cases means that poisonous substances or matters highly assimilative of oxygen are emptied into the water. The water, thus being poisonous or short of oxygen, will either kill the fish or draw the line against its migrations up and down the river.

An industrial utilization of the great and well watered river Gudenaa was of course inevitable. For the purpose of utilizing the river in the production of electricity a generating station was built at Tange in 1920. The necessary fall of the water was brought about by means of a weir across the Gudenaa west of Tange, so that a lake — the Tangesø — was formed above the dam in the valley of the river. The migrations of the sea trout and salmon are utterly prohibited by the weir. So a salmon pass was constructed at the weir for the purpose of

enabling salmon and sea trout to ascend to the spawning places above Tange. Furthermore arrangements were made that certain quantities of salmon fry should be liberated every year in the Gudenaa by the generating station. It was evidently hoped that these arrangements would remedy the damage which the Tange Generating Station must necessarily do to the fishing in the Gudenaa and the Randers Fjord. To what small extent this hope has been fulfilled will appear from the following information on the yield of the salmon and trout fishery in the Randers Fjord and the Gudenaa throughout the 14 years that have elapsed since the establishment of the Tange Generating Station.

On the decreasing yields of the salmon and trout fisheries in the Gudenaa and the Randers Fjord during recent years and the causes of the decrease.

In the following chapter a comparison will be made between the catches of salmon and sea trout in the Randers Fjord and the Gudenaa during the years before and after the establishment of the Tange Generating Station.

Table 1 is based on the statistics collected by the Board of Fisheries and gives a survey of the yield of the salmon and trout fishery in the Randers Fjord and the lower part of the Gudenaa (i. e. the whole of the distance from Udbyhøj to Tange) during the years 1913—1934. In Fig. 1 the variations of yield are represented graphically. It is evident that a marked decrease of the salmon and trout fishery has taken place during the years after 1923. From 1919 the annual average catches of 4 years' periods amounted to the following numbers of kgs.:

				Salmon	Sea trout
Annual catches during the period					
—	—	—	—	1919—22 1 008	3 702
—	—	—	—	1923—26 1 172	2 807
—	—	—	—	1927—30 37	1 996
—	—	—	—	1931—34 8	2 267

So the salmon have disappeared almost completely from the Randers Fjord and the Gudenaa during this period, and the yield of the sea trout fishery has fallen by abt. 45 per cent.

On inquiring into the cause of this enormous decrease of the trout and salmon fisheries it should in the first place be examined whether a corresponding decrease of the salmon and trout fisheries has taken place in other Danish waters or the decrease in the

Tab. 1. Yield of the salmon and sea trout fisheries in the Randers Fjord and the lower part of the river Gudenaa; (after the statistics collected by the Danish Board of Fisheries).

	Salmon		Sea trout		Total	
	kgs.	Kr.	kgs.	Kr.	kgs.	Kr.
1913	425	842	6 681	13 236	7 106	14 078
1914	835	2 530	4 685	6 900	5 520	9 430
1915	1 515	2 643	6 485	10 650	8 000	13 293
1916	1 111	3 144	4 045	10 363	5 156	13 507
1917	912	ca. 3 500	4 090	ca. 12 000	5 002	15 500
1918	975	10 350	2 997	15 970	3 972	26 320
1919	465	4 660	3 515	14 580	3 980	19 240
1920	270	2 870	1 710	7 640	1 980	10 510
1921	912	4 647	4 783	15 586	5 695	20 233
1922	2 383	8 539	4 798	16 543	7 181	25 082
1923	3 473	19 905	3 239	10 032	6 712	29 937
1924	707	6 383	3 793	19 189	4 500	25 572
1925	460	2 913	2 838	9 996	3 298	12 909
1926	47	228	1 358	4 121	1 405	4 349
1927	32	316	1 370	ca. 3 000	1 402	3 316
1928	116	575	1 913	5 508	2 029	6 083
1929	0	0	1 793	5 329	1 793	5 329
1930	0	0	2 907	8 174	2 907	8 174
1931	0	0	2 461	4 610	2 461	4 610
1932	12	60	2 746	6 212	2 758	6 272
1933	7	..	2 287	..	2 294	..
1934	13	..	1 573	..	1 586	..

Randers Fjord is an isolated phenomenon. In the subjoined table I have compared the Randers Fjord (incl. the lower part of the Gudenaa) with the Mariager Fjord, Nissum Fjord, and Skive Fjord; salmon only occur in one of these waters, the Nissum Fjord, whereas an intense fishing of sea trout is pursued in all three areas:

Area	Randers Fjord		Nissum Fjord		Skive Fjord	Mariager Fjord
	Salmon	Sea trout	Salmon	Sea trout	Sea trout	Sea trout
Annual catches in kgs. of ... during the years						
1919—22	1 008	3 702	1 308	423	13 458	6 938
1923—26	1 172	2 807	3 280	749	9 754	12 725
1927—30	37	1 996	2 436	693	10 837	15 675
1931—33	6	2 498	1 679	907	11 543	21 733

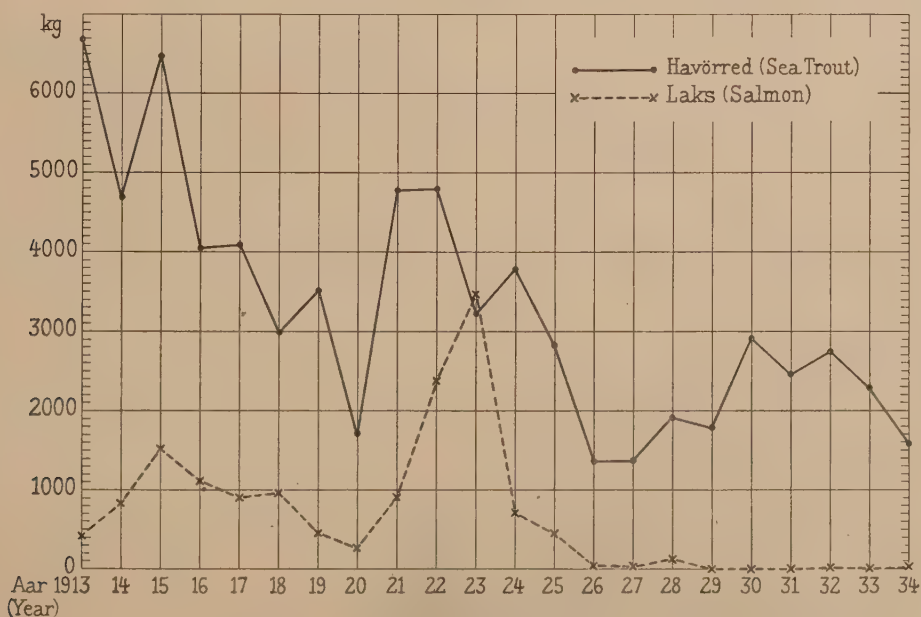


Fig. 1. Catch yields in kgs. of salmon and sea trout in the Randers Fjord and the lower part of the river Gudenaa during the years 1913—34.

It appears distinctly from the figures that as regards the salmon the Nisum Fjord does not exhibit a decrease of the same extent as the Randers Fjord during the said period. It is true that the salmon fishery of the Nisum Fjord shows an outspoken reduction within these 10 years, but this deterioration of the yields must no doubt be put down to the fact that the liberation of salmon fry in Storaæn was highly neglected during recent years. The yield of the sea trout fishery, however, has risen perceptibly in the Nisum Fjord and the Mariager Fjord whereas conditions in the Skive Fjord are very much the same as before. On the whole the figures in hand seem to indicate that the decrease of the salmon and sea trout fisheries has not come to involve large parts of our waters, but is a distinctive feature of the Randers Fjord.

It remains to investigate whether this decline of the trout and salmon fishery in the Randers Fjord and the Gudenaa should be ascribed to the weir at Tange only or other factors as well have been co-operant in the failing of the yields.

The weir of the Tange Generating Station obstructs the passage of salmon and sea trout to all their spawning places above Tange. According to A. C. Johansen & I. Chr. Løfting (l. c. 1919) the spawning places of the salmon in the Gudenaa were situated between Tange and Resenbro, above Tange; at the time the salmon undoubtedly spawned in the Borreaa and the Tangeaa as well, both of which fall into the Gudenaa above Tange. Below Tange the salmon did not spawn, neither in the Gudenaa itself nor in tributaries of the river or the Randers Fjord (as for instance the Allingaa). So the

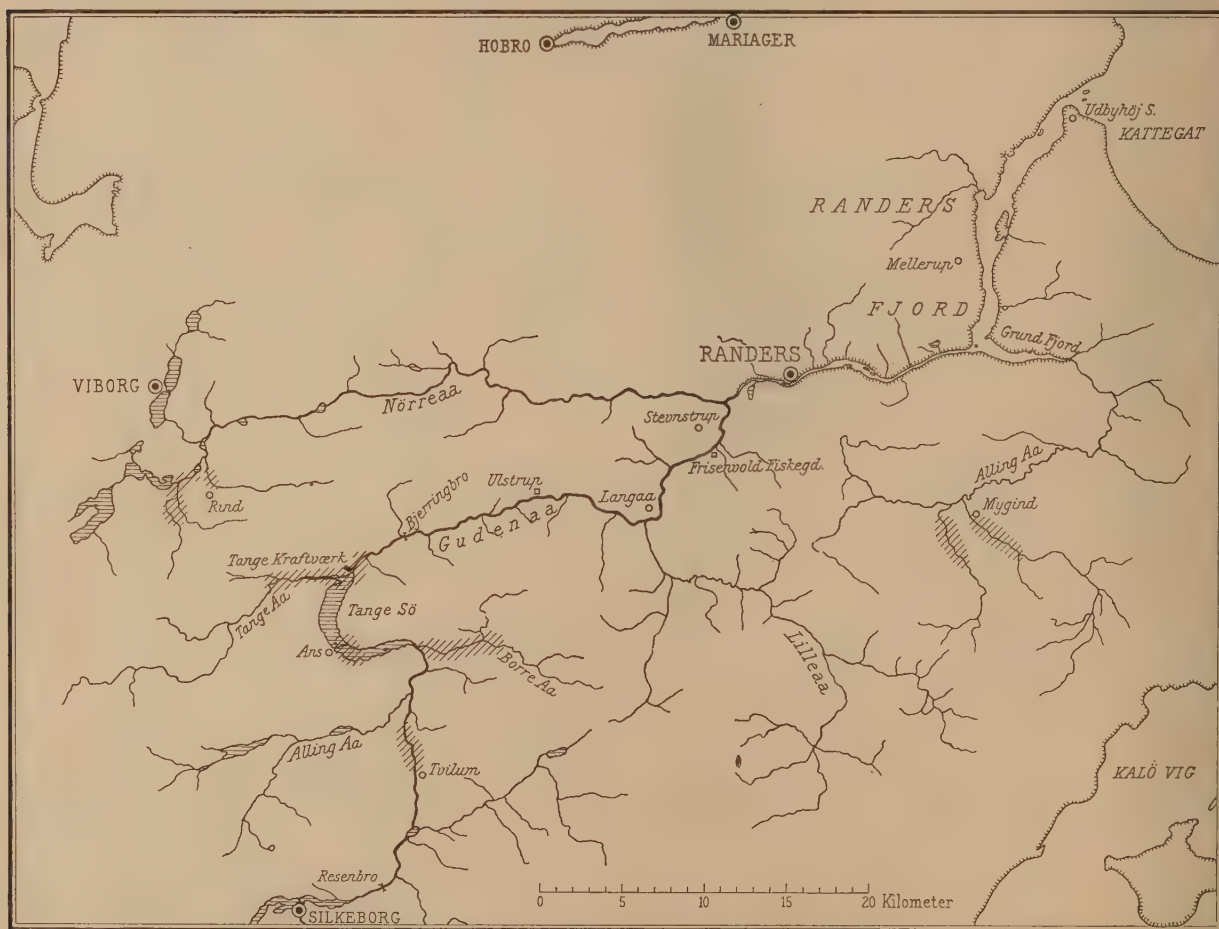


Fig. 2. Midmost and lower part of the river Gudenaa and the Randers Fjord with the situations of the principal spawning places of the sea trout.

building of the Tange Weir barred the access to all spawning places of the salmon within the Gudenaå area. To the sea trout conditions are less unfavourable. The localization of its spawning places in Fig. 2 is based partly on the investigations of Johansen & Løfting, partly on information received from Mr. Skaanning, Fishery Official of Randers. Before 1920 the sea trout spawned extensively above Tange, especially in the Tangeå and the Borreå, but moreover important spawning places were found in various tributaries of the Gudenaå below Tange, for instance in the Nørreå and, to a less degree, in the Lilleå, in some brooks and finally in the Allingå (falling in the Randers Fjord) with various tributaries. As mentioned above the Tange Weir shut out the salmon from all its spawning places, and also the greater part of those of the sea trout were barred. The said salmon pass was built in order to remedy this drawback, but there is every indication that it has not answered its aim.

From the years after 1923 we have statistics informing us of the catches of fish in the Tangesø (immediately above the Tange Weir). 1923—33 no salmon were caught in the Tangesø, whereas the landings of trout were as follows:

Year	1923	1924	1925	1926	1927	1928
kgs. of trout	18	120	0	7	7	46
Year	1929	1930	1931	1932	1933	
kgs. of trout	37	36	53	104	0	

The greater part of trout dealt with in these statistics must be supposed to be lake trout or brown trout both of these forms being frequent in the Gudenaå area. As late as 1923—25 the catches of salmon and sea trout in the Randers Fjord were rather heavy; consequently there must have been a considerable ascent of these fish into the Gudenaå, and so the very light catches in the Tangesø mean that only inconsiderable numbers of these species have forced their way through the salmon pass. In spite of the pass the Tange Weir has been an insuperable obstacle to the salmon and sea trout ascending. We will begin by looking into the effects of this barring as concerns the salmon.

A. C. Johansen's and I. Chr. Løfting's examinations of salmon caught in the Friesenvold fish-weir¹⁾ show that the ascent of salmon takes place prin-

cipally during the months of January—August, in other words from nearly twelve months till only three months before the spawning would take place. The same facts emerge from statistics of the catches of salmon in the Randers Fjord (s. Table 7 b p. 25); here the major part of salmon is caught in March—July, whereas only smaller quantities are taken in August—February. This again means that most of the salmon that were to spawn in the autumn of 1920 and the winter of 1920—21 had been able to ascend to the spawning places before the Tange Weir was closed on October 1st, 1920. But no doubt the much working with earth in connexion with the building of the weir have contributed to interrupting the ascent already in the summer of 1920. Already in 1920 a limited ascent of the mother fish must therefore undoubtedly be taken into account, so that there is already some reduction of the salmon fry appearing in the spring of 1921. To all subsequent year-classes of mother fish there has been no natural access at all to the spawning places. We know that most salmon emigrate from the Gudenaå at an age of two years, and furthermore (according to information given by Mr. Skaanning, Fishery Official) that no salmon smolts have been observed in the Gudenaå and the Randers Fjord later than 2—3 years after the closing of Tange¹⁾, a fact that seems to indicate that salmon fry appeared for the last time in the Gudenaå in the spring of 1921. According to Johansen & Løfting most of the salmon entering the Gudenaå and the Randers Fjord are 3—5 years old. Consequently the unfavourable effects of the closing of Tange would appear in 1924 at the earliest and increase constantly during the following years; in 1928 only some "lingerers" and some few of the salmon that spawn more than once²⁾ would be left, and one or two years later — still assuming that no fry has appeared since the spring of 1921 — it would be possible in the Randers Fjord to catch only the few salmon that have strayed into these waters from other (Swedish) rivers.

The close accordance of these suppositions with the present conditions appears from Fig. 1, which represents the yield of the salmon fishery in the Randers Fjord and the Gudenaå. In 1922 and 1923 the annual catches of salmon amounted to 3 000 kgs., but in 1924 they had fallen to 700 kgs. and in 1925

¹⁾ One individual was observed in the spring of 1927.

²⁾ Johansen & Løfting state that abt. 4 % of the salmon examined had spawned more than once.

¹⁾ I. c.

to little more than 400 kgs.; in 1926 the yield was 47 kgs., in 1927 and 1928 32 and 116 kgs., respectively, and finally from 1929 onwards only one or two salmon were caught a year. Whether these few salmon from the years since 1929 originate from an extremely small spawning in the Gudenaa or they have strayed in from other (Swedish) rivers cannot be decided. In other words the years after the erection of the Tange Generating Station have witnessed the complete or nearly complete extinction of the salmon in the Gudenaa and the Randers Fjord, and the fact that the salmon disappeared in 1924—28 of all years leaves no doubt that — despite of the salmon pass — the Tange Station is the cause of its disappearance.

Down to 1920 the sea trout (see map Fig. 2) spawned both above and below Tange, and so, unlike the salmon, it has had access to some of its old spawning places in the years after 1920; consequently we do not expect to find so large a decrease in the yield of the sea trout fishery as in that of the salmon fishery. The biology of the sea trout is in many respects very like that of the salmon; most of the smolts of sea trout emigrate at an age of abt. 2 years, and the ascent from the sea takes place abt. 1—3 years later; so we would expect a decrease to appear in the years about 1924. As a matter of fact we find such a decrease: the years 1921—22 show an annual yield of nearly 5 000 kgs., 1923 and 1924 little more than 3 000 kgs., and 1926 and 1927 well over 1 300 kgs. a year. During the following years, until 1932, there is a small rise, the annual yield, however, never rising more than a little above 2 700 kgs. In 1933 and 1934 the yield declines once more, being abt. 2 300 and 1 600 kgs., respectively.

The survey below gives the yields of the salmon and sea trout fisheries in the Randers Fjord and the Gudenaa before and after the effects of the Tange Weir asserted themselves (heading "Before" states the annual average yield of the period 1913—23, and "After" the corresponding figures of the period 1924—34. The statements of value for both periods are based on the value of salmon and trout in 1933):

	Salmon		Sea trout	
	kgs.	Kr.	kgs.	Kr.
Before	1 207	4 997	4 235	9 021
After.....	5	21	2 295	4 888
Decrease...	1 202	4 976	1 940	4 133

In other words the yield of fisheries in the Randers Fjord and the Gudenaa has declined by abt. 10 000 Kr. on account of the decreasing catches. The figures may seem small, but in fact the fishermen of the Randers Fjord are now earning 12 % less than they would have done if this decrease had not occurred¹⁾.

Growth of the sea trout in the river and its migration to the sea.

According to Johansen & Løfting the fry of the sea trout attains a length of 7—10 cm. during its first year of life; during the second year of its stay in the river its length increases to abt. 18 cm. Most individuals migrate to the sea at an age of 2 years, a small number, however, emigrating already when 1 year old, while some few individuals do not emigrate until they are 3 years old.

The material of these late years shows much the same conditions. Table 2 gives the lengths of smolts of sea trout caught in the Randers Fjord during the descent in spring. It appears from this table that barely $\frac{1}{5}$ descend when one year old and $\frac{4}{5}$ when two years old, while quite a few specimens do not descend until they have stayed three years in fresh water. The length of the one-year-old smolts ranges between 12 and 18 cm., their average length being abt. 15 cm. The length of the two-years-old smolts varies from 14 to 27 cm, averaging 20.1 cm.

An examination of the scales of 287 sea trout caught in the Randers Fjord or the Gudenaa after a stay in the sea results in the following figures as regards the duration of the stay in the river before the descent:

1 year in fresh water before descent	56 individuals or	20 %
2 years - — — — —	226 —	78 %
3 — — — — —	5 —	2 %

On the whole the figures found here are in accord with the direct examinations of smolts as well as the results of Johansen's & Løfting's examination of the scales of 106 specimens of old sea trout from the years 1911—16:

1 year in fresh water	20 individuals or	19 %
2 — — — — —	85 —	80 %
3 — — — — —	1 —	1 %

¹⁾ In 1933 the fishery in the Randers Fjord yielded a profit of 76 320 Kr.

Tab. 2. Length and age of sea trout smolts caught in the Randers Fjord in April—June.

Age	1 year				2 years				
Date	7/4-35	27/4-30	6/6-30	Total	7/4-35	27/4-30	23/6-29	6/6-30	Total
cm.									
12	..	1	..	1	..	..	..	..	..
13	..	1	..	1	..	..	..	..	..
14	..	1	..	1	..	1	..	..	1
15	..	3	..	3	1	1	..	..	2
16	1	1	..	2	..	4	..	..	4
17	..	..	..	..	1	2	..	..	3
18	..	..	2	2	2	2	1	..	5
19	..	..	..	..	2	..	..	1	3
20	..	..	..	..	..	2	1	2	5
21	..	..	..	..	1	2	..	3	6
22	..	..	..	..	2	1	3	..	6
23	..	..	..	..	..	..	..	3	3
24	..	..	..	..	1	..	1	..	2
25	..	..	..	..	2	..	..	..	2
26	..	..	..	..	..	..	1	..	1
27	..	..	..	..	..	..	1	..	1
Total.....	1	7	2	10	12	15	8	9	44
Mean length cm.	16.0	14.4	18.0	15.2	20.4	17.8	23.0	21.2	20.1

So we see that the altered situation of the spawning places of the sea trout that has been brought about by the building of the Tange Weir in a way as to bar the access to the upper spawning places, has in no way affected the duration of the stay in fresh water.

If we look at the length¹⁾ of the smolts (Table 2), we see that the smallest one-year-old smolts are 12 cm. and the smallest two-years-old ones are 14 cm. long while the average lengths of these two groups of smolts were 15.3 and 20.1 cm. The greatest lengths found within these two groups are 18 cm. for the one-year-old smolts and 27 cm. for the two-year old ones. That the fast-growing parrs emigrate at an younger age than the slow-growing ones will appear from the measures showing the breadth of the different zones of growth on the scales. In these calculations (according to the rules generally applied) l_1 stands for the length at the end of the first year of life (the first growth period), l_2 for the length at the end of the second year, etc. The subjoined table states the calculated values of l_1 as regards 1-, 2-, and 3-years-old smolts:

cm.	l_1 in		
	1-year-old	2-years-old	3-years-old
5	..	21	1
6	1	55	3
7	3	77	1
8	7	43	..
9	8	12	..
10	14	11	..
11	9	..	..
12	4	..	..
13	7	1	..
14	1	..	..
15	1	..	..
Total...	55	220	5
Average...	10.2	7.0	6.0

It appears from the table that the individuals descending at an age of one year show the most rapid growth during their first year of life (10.2 cm.); the two-years-old smolts display a rather inferior growth (7.0 cm.) during their first year of life, while the 5 three-years-old individuals show the lowest average growth calculated (6.0 cm.). The average lengths calculated in this way do not quite correspond to the real average lengths but are somewhat lower. As an instance may be mentioned that the average length of 7 sea trout caught at an age of one year during the descent in April was 14.5 cm. as against the calculated length of 10.2 cm. Accordingly,

¹⁾ All measures have been reduced to the nearest integer below, so that for instance 26.0—26.9 cm. is given as 26 cm. On account of its being calculated on the basis of these integers, the average length is always 0.5 cm. too low.

l_1 does not denote the length on the close of the first year, but is only expressive of the growth, which, however, would suffice for the use made of it in this place. That the rapidly growing individuals of a year class emigrate before the slowly growing ones is apparently a fact of universal validity. From his investigations in Scotland W. I. M. Menzies¹⁾ reports that "the average length of parr which migrate at a particular age is always greater than that of the parr of the same age which remain for an additional year, or years, in fresh water."

In the scales of some few of the sea trout examined I observed, outside the fresh water zone, a growth zone, which takes up an intermediate position between the growth zones of the fresh water and the sea respecting its entire width and the breadth of the individual sclerites. Apparently these sea trouts did not migrate directly from the river to the sea, but stopped in the brackish water of the Randers Fjord, where they stayed for a year before definitely migrating to the sea. The material in hand offered 10 individuals, which in my opinion must decidedly be placed within this group. 4 of them had spent one year and 6 of them two years in fresh water before descending into the Fjord. The growth rate in the Fjord is somewhat higher than in the river but not so high as in the sea: the average growth of the year spent in the Fjord by the 10 individuals was calculated to be 13 cm. We also have direct observations as to the occurrence of such "fjord trout" in the Randers Fjord: the 3 trout mentioned below were caught in seine in the Randers Fjord on 15-VIII-29; they must undoubtedly be included under this group:

26.5 cm., female, im., 2. + years²⁾ 165 g., stomach contents:
4 small herrings.

25 cm., female, im., 2. + years, 155 g., empty.

26 cm., male, im., 2. + years 165 g., stomach contents:
remains of small herrings.

The sea life of the Gudenaa trout.

When in the course of spring the young sea trout have entirely left the Randers Fjord they go by

preference in a southwards direction along the coast. Mr. Skaanning reports that considerable quantities of young and — judging by the size — recently descended sea trout are caught in pound nets on the coast S. of Udbyhøj; whereas only few specimens are taken in pound nets N. of the mouth of the Fjord. Mr. Madsen, Fishery Official of Grenaa, has reported to me that undersized trout appear on the coast of Djursland (i. e. S. of the Randers Fjord) in April, May, and June; during these months as much as 25 undersized trout may be caught a night in each pound net. The experimental markings of descending sea trout in the mouth of the Randers Fjord carried out by Johansen & Løfting also indicate a southward bend of the migration: during the first and second month after the liberation 4 individuals were recaptured S. of Udbyhøj, but none of the trout marked were caught N. of the Fjord. Later on 2 individuals were recaptured S. of the Randers Fjord, viz. 1 in the Great Belt and 1 in the Western Baltic.

The young sea trout will stay in the immediate vicinity of the coast — at any rate during the first summer after their descent: in 1931 the pound nets from Udbyhøj and down towards Grenaa were placed close on the coast, and many young sea trout were caught in them; in 1932 they were placed farther seawards (for mackerel) and caught but few young sea trout. This pound net fishery on the coast as well as the weel fishery in the Randers Fjord apparently does much harm to the stock of sea trout. When the pound nets were drawn, I often observed nearly 50 undersized sea trout in the gears, and although some of them may be uninjured and likely to live, no doubt many of them will perish. The weels in the Randers Fjord often contain 50—100 undersized sea trout at a time. Of course the sea trout fishery is of slight importance as compared with the pound net fishery, so that restrictions of the latter fishery for the benefit of the young sea trout are surely out of the question. We may only hope that in drawing their gears the fishermen will be careful in handling the young sea trout, which may live to be very valuable fish in a year or two. It would, however, be worth considering — in return for enlarged transplantations of fry of sea trout — to make certain restrictions in the weel fishery in the Randers Fjord during the months of April and May, the time when the sea trout emigrates from the river.

¹⁾ Report of the meeting of salmon and trout experts in Poland — Oct. 1933. Rapp. et Proces Verbaux XCI, 1934.

²⁾ In the statements of age the number of complete growth periods (April—October) in river are given before full stop and the number of complete growth periods in sea after full stop; + denotes that beside the number of years stated the individual has further spent some months of another growth period.

The growth after the descent into the sea.

The statements above (p. 14) have shown that the sea trout descending from the Randers Fjord into the sea are of rather different ages. In considering age and length we establish the following distribution:

- 1 year in the river: average length 15.3 cm., the group constituting 20 % of the fish descending.
- 2 years in the river: average length 20.1 cm., the group constituting 78 % of the fish descending.
- 3 years in the river: average length ? cm., the group constituting 2 % of the fish descending.

To these categories should be added the small group of "fjord trout", which spend an intermediate year in the Fjord; this group only constitutes 3 % of the individuals examined. No individuals have been observed to spend two years in the Fjord. Accordingly, the age of the sea trout reaching the sea ranges between 1 and 4 years, the bulk of them — more than $\frac{3}{4}$ — being two years old.

In the following investigations into the growth in the sea these various groups of descending fish will be treated as a unit without regard being paid to the varying duration of stay in fresh water. As regards the few individuals that have stayed for some time in the Fjord before the final emigration, this stay has been considered as a period spent in the sea, the growth rate of the Fjord being more like that of the sea than that of the river.

Table 3 gives the lengths of 177 sea trout caught in the Gudenaa or the Randers Fjord after a 1—6 years' stay in the sea; the table only includes individuals that have been caught during the period October—March, i. e. individuals that have covered the whole period of growth. The average length and the maximum and minimum lengths observed emerge from the following survey:

Growth periods (summers) in the sea	No. of ind.	average length in cm.	minim. length in cm.	maxim. length in cm.
1 first salt water series	65	39.6	31	49
2 second —	61	54.4	43	69
3 third —	25	64.5	56	75
4 fourth —	18	76.6	68	89
5 fifth —	7	79.4	60	89
6 sixth —	1	81.0	..	..

Johansen & Løfting give analyses of age and growth of silvery trout caught in the Randers Fjord

in January and February 1916. The authors found the first salt water series to have an average length of 39.5 cm. (36 ind.), the second 55.9 cm. (21 ind.), and the third salt water series 61.7 cm. (3 ind.). Thus a close accordance exists between the two series of analysis. The disappearance of a series of spawning

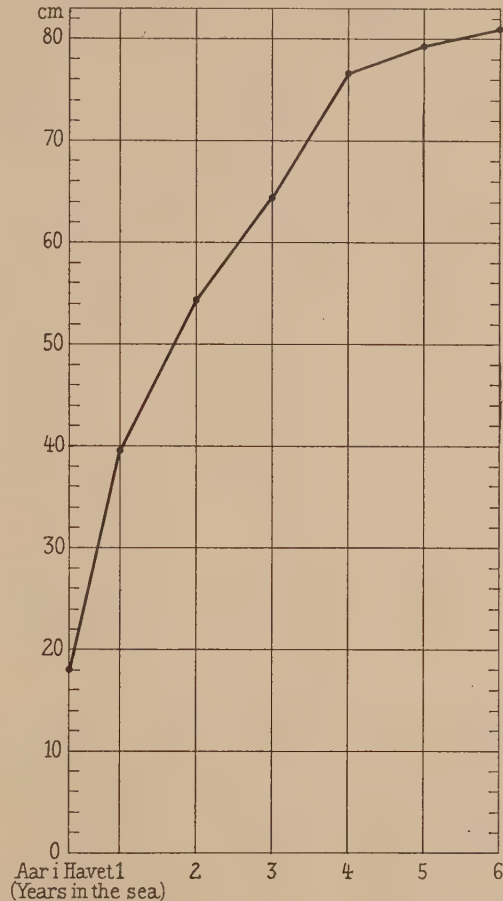


Fig. 3. Growth of the Gudenaa sea trout after emigration to the sea.

places within the Gudenaa and the resulting increase in numbers as well as in proportion to the ordinary amount of fry, of artificially hatched fry (partly from other streams) has had no unfavourable influence on the growth of sea trout.

If we put the length of the descending trout at 20 cm., the growth (s. Fig. 3) during the first year in the sea amounts to 20 cm.; during the second year of the sea life the growth is 15 cm., the third 10 cm., the fourth 12 cm., and the fifth 3 cm. In other words the rate of growth decreases with the increasing age:

it is highest during the first year of the sea life, somewhat lower during the second, third, and fourth year, and very low from the fifth year in the sea.

The largest sea trout caught in the Gudenaa have a length of abt. 1 m. and a weight of 12—13 kgs. During the period 1899—1914 the largest sea trout was caught in October 1906; it had a length of 103 cm. and weighed abt. 13 kgs. (Johansen & Løfting). During the period 1920—34 the largest sea trout measured was 97 cm. long and weighed abt. 12 kgs.; it was a mature male and was caught in the Fjord near Randers in September 1930. Its age was 2.3+ years, the comparatively young fish having spent 2 growth periods in the river and nearly 4 in the sea. The oldest sea trout observed in the

years 1920—34 was a mature female of 81 cm., which was 8 (2.6) years old.

Of the two younger salt water series fairly large numbers of individuals were examined; Table 3 gives the lengths of males and females separately (the sex of some individuals not being stated, the number of individuals in these columns is smaller than in the first column of the table).

It appears from the figures stated that the females, as is generally the case in fish, at any rate during their earliest years, display a somewhat higher rate of growth than the males. The males of the first salt water series have an average length of 38.7 cm. (34 ind.), the females of 40.0 cm. (23 ind.), the difference, 1.3 cm., being but slight. Of the second salt

Tab. 3. Length of sea trout caught in the Randers Fjord and the river Gudenaa after 1—6 years of sea life.

Years of sea life	1	2	3	4	5	6	1		2	
Sex							♂	♀	♂	♀
31 cm.	1	..	..	..	..	..	1	..	..	..
32 -	2	..	..	..	..	..	2	..	..	..
33 -	1	..	..	..	..	..	..	1	..	..
34 -	2	..	..	..	..	..	1	..	..	..
35 -	..	..	..	..	..	..	..	..	..	..
36 -	6	..	..	..	..	..	4	2	..	..
37 -	9	..	..	..	..	..	6	3	..	..
38 -	5	..	..	..	..	..	4	..	..	..
39 -	4	..	..	..	..	..	1	3	..	..
40 -	6	..	..	..	..	..	2	3	..	..
41 -	7	..	..	..	..	..	4	2	..	..
42 -	10	..	..	..	..	..	5	5	..	..
43 -	3	1	..	..	..	..	1	1	..	..
44 -	4	..	..	..	..	..	2	2	..	..
45 -	2	2	..	..	..	..	1	1	2	..
46 -	..	1	..	..	..	..	..	..	..	1
47 -	1	..	..	..	..	..	..	..	..	..
48 -	1	..	..	..	..	..	..	..	..	..
49 -	1	2	..	..	..	..	..	..	2	..
50 -	..	9	..	..	..	..	..	..	3	6
51 -	..	4	..	..	..	..	..	..	2	2
52 -	..	4	..	..	..	..	..	..	2	2
53 -	..	5	..	..	..	..	..	..	3	2
54 -	..	3	..	..	..	..	..	..	1	2
55 -	..	4	..	..	..	..	..	..	2	2
56 -	..	6	1	..	..	..	..	..	3	2
57 -	..	5	..	..	..	..	..	..	1	4
58 -	..	6	..	..	..	..	..	..	..	6
59 -	..	..	..	..	..	..	..	..	..	..
60 -	..	4	8	..	1	..	..	..	1	3
61 -	..	1	..	..	..	..	..	..	1	..
62 -	..	..	3	..	..	..	..	..	..	..
63 -	..	1	1	..	..	..	..	..	1	..
64 -	..	1	..	..	..	..	..	..	..	1
65 -	..	..	..	..	..	..	..	..	..	..
66 -	..	..	3	..	..	..	..	..	..	..

Years of sea life	1	2	3	4	5	6	1		2	
Sex							♂	♀	♂	♀
67 cm.	..	..	1	..	..	..	..	..	..	..
68 -	..	1	2	1	..	..	..	..	..	..
69 -	..	1	..	..	1	..	..	..	..	..
70 -	..	..	4	1	..	..	..	..	..	..
71 -	..	..	1	2	..	..	..	..	..	..
72 -	..	..	..	2	..	..	..	..	..	..
73 -	..	..	..	..	..	..	..	..	..	..
74 -	..	..	..	1	..	..	..	..	..	..
75 -	..	..	1	2	..	..	..	..	..	..
76 -	..	..	..	1	..	..	..	..	..	..
77 -	..	..	..	..	..	..	..	..	..	..
78 -	..	..	..	3	1	..	..	..	..	..
79 -	..	..	..	..	..	..	..	..	..	..
80 -	..	..	..	1	..	..	..	..	..	..
81 -	..	..	..	1	..	1	..	..	..	..
82 -	..	..	..	..	..	..	..	..	..	..
83 -	..	..	..	..	..	..	..	..	..	..
84 -	..	..	..	..	..	..	..	..	..	..
85 -	..	..	..	2	1	..	..	..	..	..
86 -	..	..	..	..	1	..	..	..	..	..
87 -	..	..	..	..	..	..	..	..	..	..
88 -	..	..	..	..	..	..	..	..	..	..
89 -	..	..	..	1	2	..	..	..	..	..
No.	65	61	25	18	7	1	34	23	24	33
Mean length, cm.	39.6	54.4	64.5	76.6	79.4	81.0	38.7	40.0	53.2	54.8

water series the average length of the males is 53.2 cm. (24 ind.), of the females 54.8 (33 ind.), the difference being 1.6 cm.

After 1 and 2 growth periods in the sea a difference in length, however slight, may still be observed to exist between the sea trout that have descended at an age of one year and those which have descended when two years old:

1 year in fresh water and 1 year in sea	37.5 cm. (18 ind.)
2 years in fresh water and 1 year in sea	40.1 cm. (47 ind.)

Difference... 2.6 cm.

1 year in fresh water and 2 years in sea	52.3 cm. (16 ind.)
2 years in fresh water and 2 years in sea	55.2 cm. (43 ind.)

Difference... 2.9 cm.

The difference in average length between one- and two-years-old smolts is abt. 5 cm. on the descent, and so we notice that as regards the size the one-year-old fish gain upon the two-years-old during the stay in the sea, which means that the growth rate of the former still is a little higher than that of the latter.

Length at the end of the different growth periods, calculated by the breadth of the zones of growth in the scales.

It is a well-known fact that the scales of a fish will grow in proportion to the fish itself, so that, given the length of the fish, it is possible by measuring the breadth of the different zones of growth in the scales to calculate the length of the fish at the end of every year. The length calculated in this way is designated by the letter "*l*", and to this letter is added a figure, stating the age that corresponds to the length calculated; thus "*l*₁" denotes the calculated length on the end of the first year of life, "*l*₂" on the end of the second year, and so on. As regards the sea trout and salmon, the growth rate of which differs widely in fresh and in salt water, "*l*₁" means the growth during the first year in fresh water, "*l*₂" during the second year in fresh water, while "*l*₁" denotes the growth during the first, "*l*₂" during the second year in the sea.

On the basis of the material of scales collected calculations of this kind were made, yielding the following values of *l* during the stay in fresh water:

l_1 . 7.7 cm. (260 ind.)
 l_2 . 15.1 - (228 —)
 l_3 . 22.0 - (5 —)

In the case of l_1 and l_2 , we have a material of direct observations of length at the end of the first and second year of the river life. The figures below give a comparison between the length directly observed and the length calculated:

	At the end of	
	first year in river	second year in river
Length calculated	7.7 cm.	15.1 cm.
Length directly observed.....	abt. 9 -	20.1 -

Thus the length calculated does not quite correspond to the real length, particularly not after the second year of life where there is a difference of 5 cm.; the calculated length being abt. 25 % too low.

The proportion of the length calculated to the length directly observed during the sea life appears from the following figures:

- l_1 = 36 cm. — length directly observed after 1 year in the sea: 39.6 cm.
 l_2 = 53 cm. — length directly observed after 2 years in the sea: 54.4 cm.
 l_3 = 67 cm. — length directly observed after 3 years in the sea: 64.5 cm.
 l_4 = 76 cm. — length directly observed after 4 years in the sea: 76.6 cm.

Thus after the first year of the sea life the length calculated is abt. 4 cm. below the length directly observed, but after the second year of the sea life it is only 1.5 cm. lower. However, after the third year in the sea the length calculated is just a little higher than the length directly observed, while after the fourth year in the sea the two lengths are nearly the same.

Though there is no absolute correspondence between the lengths calculated and the real lengths, still the former may be used for the purpose of investigating in how far individuals, starting with a slow or rapid growth, retain this character of growth during their later years.

In this connexion we will at first examine the growth during the two years of river life. Table 4, which takes in individuals that have lived in the river for two years, indicates within each group in cm. of l_1 . (the growth during the first year of life) the lengths calculated after the second year of life (l_2). The table shows us that a slow growth during the

Tab. 4. Growth in 1st year of river life compared with growth in 2nd year of river life, based on the calculated lengths (l_1 and l_2).

l_2	l_1 ...	5 cm.	6 cm.	7 cm.	8 cm.	9 cm.	10 cm.
10 cm.....	1	..	1	..	..	..	..
11 -	8	4	..	1	..	..	..
12 -	6	10	2	..	..	..	..
13 -	4	14	7	1	..	..	..
14 -	1	9	14	7	..	..	..
15 -	1	13	26	7	2	..	..
16 -	..	4	10	11	2	..	..
17 -	1	2	5	6	1	..	..
18 -	..	..	5	6	4	4	4
19 -	..	1	..	3	2	5	5
20 -	..	..	2	1	..	1	1
21 -	..	..	..	1	1	1	1
No.	22	57	72	44	12	11	11
Mean length, cm.	12.2	13.8	15.1	16.2	17.5	18.9	18.9

first year gives a slow growth of the second year as well, while a rapid growth during the first year is followed by a rapid growth in the second: individuals, the calculated length of which was 5 cm. after the first year, only reached an average length of 12.2 cm. during the second year, while individuals with a growth of 10 cm. during the first year had attained a length of 18.9 cm. after two years. The distance of 5 cm. gained by the latter group in the first year of life increased to 6.7 cm. during the second year of life. The question remains whether this different growth rate of the individuals is maintained during their subsequent stay in the sea. By way of answer the subjoined table, within each group in cm. of l_1 . (the growth during the first year in the river), compares the calculated average lengths of the second year in the river (l_2) with those of the first and second year in the sea (l_1 and l_2); the numbers of individuals examined are given in brackets:

l_1	l_2	l_1	l_2
5 cm.....	12.2 (22)	36.8 (16)	51.4 (8)
6 -	13.8 (57)	35.9 (39)	51.4 (25)
7 -	15.1 (72)	36.2 (56)	53.3 (38)
8 -	16.2 (44)	37.5 (30)	54.9 (18)
9 -	17.5 (12)	36.7 (11)	53.0 (8)
10 -	18.9 (11)	39.7 (11)	54.4 (8)

The average value of the calculated lengths after the first and second year in the sea (l_1 and l_2) do not show the same regularity of distribution as the corresponding lengths after the second year in the river. However, the difference between the highest and lowest figures (36.8—39.7 and 51.4 and 54.4 cm.) is

but small (3—4 cm.), even somewhat smaller than the corresponding difference of l_1 (5 cm.) and considerably smaller than the difference between the highest and lowest value of l_2 (6.7 cm.). This fact means that the difference in size between the fast and slowly growing individuals of the river will gradually diminish during the stay in the sea. Or in other words: the individuals growing rapidly during their river life will not retain this rapid growth during sea life. Accordingly, in the case of the Gudena trout, the rate of growth is not a permanent characteristic of the individual but depends on the conditions under which the individual may come to live.

The ascent of the sea trout from the sea.

a. Investigations based on analyses of scales.

When the sea trout ascend the Randers Fjord and the Gudena the period spent in the sea may have

lasted a few months or several years. If the stay in the sea lasts for several years, it is — at any rate in some cases — interrupted by one or several short visits (sometimes of some months) in fresh water or the brackish water of the Fjord.

Basing on scale analyses of abt. 300 sea trout, which have ascended the Gudena or the Randers Fjord and have not yet finished their spawning, Figs. 4 a and b give a survey of length and age of sea trout caught in the Randers Fjord and the Gudena in the various months of the year (s. also Table 5). On account of the partial protection in November and December the material of these two months is not representative of the stock. “. + — .1” denotes individuals caught at a time when a whole year had not yet elapsed after the descent into the sea (the time of emigration was fixed at April, 1st); “. +” denotes individuals caught from April 1st till September 30th; “.1” individuals caught within the time October 1st—March 31st. The group “.1 + — .2”

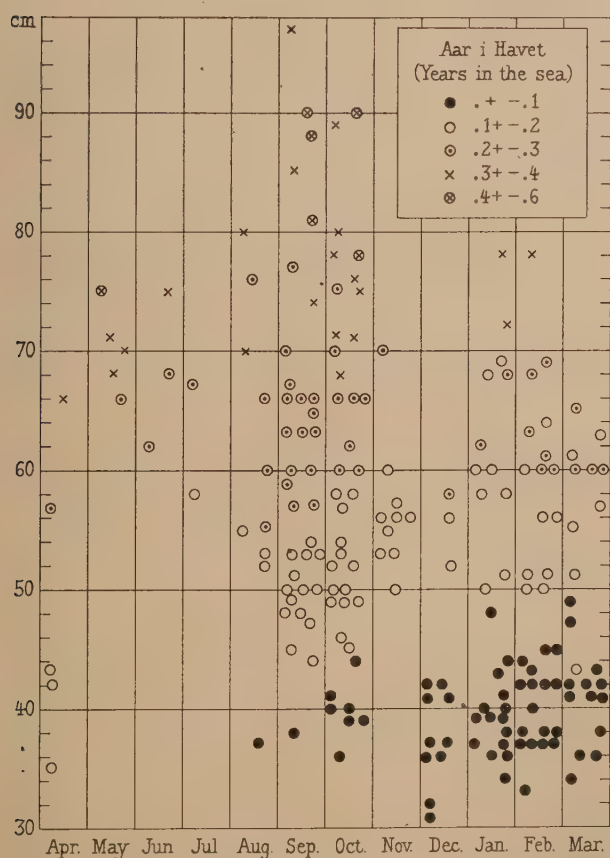


Fig. 4a. Length and age (number of years spent in the sea) of sea trout caught in the Randers Fjord during the different months of the year (1920—34).

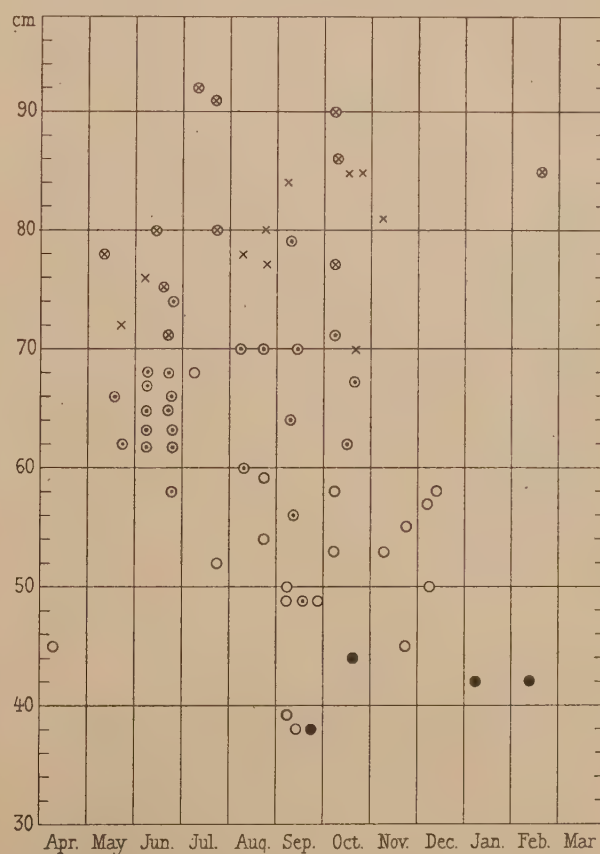


Fig. 4b. Length and age (number of years spent in the sea) of sea trout caught in the lower part of the Gudena during the different months of the year (1920—34).

Tab. 5. Catches of sea trout of various ages of sea life in the different months of the year in the Randers Fjord and in the river Gudenaa.

		Years in the sea	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Tot.
River	1. salt water series	.0+—.1	1	1	..	..	..	..	..	..	1	1	..	..	4
	2. —	.1+—.2	..	..	..	1	..	..	2	2	5	2	3	3	18
	3. —	.2+—.3	..	..	..	..	2	12	..	3	5	3	..	..	25
	4. —	.3+—.4	..	..	..	..	1	1	..	3	1	3	1	..	10
	5. — and older	.4+—.6	..	1	..	..	1	3	3	..	..	3	..	..	11
Total...			1	2	..	1	4	16	5	8	12	12	4	3	68
Fjord	1. salt water series	.0+—.1	15	17	13	..	..	..	..	1	1	7	..	10	64
	2. —	.1+—.2	8	8	6	3	..	..	1	3	14	14	9	2	68
	3. —	.2+—.3	2	6	4	1	1	2	1	4	15	8	1	1	46
	4. —	.3+—.4	2	1	..	1	3	1	..	2	3	8	..	..	21
	5. — and older	.4+—.6	..	..	..	..	1	..	..	..	3	2	..	..	6
Total...			27	32	23	5	5	3	2	10	36	39	10	13	205

includes sea trout that have spent more than one but not two whole years in the sea; “.2+—.3” means individuals that have spent more than two but not wholly 3 years in the sea, “.3+—.4” individuals between 3 and 4 years, and finally the group “.4+—.6” is composed of trout that have spent 4 years or more in the sea. The figures also include such sea trout as have formerly ascended the river for the purpose of spawning.

To begin with we shall look at the youngest group (.+—.1), individuals that have spent twelve months or less in the sea, the so-called first salt water series. It appears from Fig. 4 a that this group (represented by black dots in the figure) is numerously represented in the Fjord in winter. Small quantities begin to appear in August—September, in October there is a considerable rise in the number of individuals, and during the winter months and early spring (March) the group is very rich in individuals. But in the beginning of April very few individuals are left in the Fjord (belonging to the next age group they are marked down as circles in the figure), and

in the months of May, June, and July this series was not observed at all in the Fjord. Thus this first salt water series begins to ascend the Fjord late in summer or early in autumn, and it descends in spring (March—April).

The length of the individuals of the first salt water series average 40 cm., the weight ranging between abt. 0.5—0.75 kg. The distribution as to sex and maturity appears from Table 6. It will be noted that the first salt water series consists nearly exclusively of immature, silvery fish, only 2 out of 58 individuals being mature (females of 40 and 41 cm.). The males are in the majority: 36 males against 22 females. Only quite a small number of the individuals of this group will ascend from the Fjord into the river (s. Fig. 4 b). Of the material investigated only the following 4 individuals were caught in the very river:

1. $\frac{15}{9}$ -1924, at Tange, male, 38 cm., silvery,
2. $\frac{19}{7}$ -1920, — — female, 44 cm., silvery,
3. $\frac{9}{1}$ -1930, — Langaa, male, 42 cm., silvery,
4. $\frac{11}{1}$ -1934, — Bjerringbro, female, 44 cm., silvery.

Tab. 6. Sex and maturity of sea trout of different ages caught in the Randers Fjord and the river Gudenaa after return from the sea.

Duration of sea life	Fjord				river				Fjord + river			
	♂♂		♀♀		♂♂		♀♀		♂♂		♀♀	
	im.	m.	im.	m.	im.	m.	im.	m.	im.	m.	im.	m.
.+—.1	33	0	19	2	3	0	1	0	36	0	20	2
.1+—.2	18	0	23	5	1	4	4	6	19	4	27	11
.2+—.3	4	4	17	9	3	2	9	8	7	6	26	17
.3+—.4	4	2	4	0	4	1	1	5	8	3	5	5
.4+—.6	0	1	1	3	4	2	7	1	4	3	8	4
Total...	{ 59 7 }		{ 64 19 }		{ 14 9 }		{ 21 20 }		{ 73 16 }		{ 85 39 }	
	66		83		23		41		89		124	

From a biological point of view one specimen of the next age group (2.1+, 45 cm., silvery) caught in the Gudenaå on 2-IV-1932 should be included in this group. These five individuals from the Gudenaå were all of them silvery fish, and all of them — or at any rate 3 of them — being captured rather close on the spawning time, it is an obvious conclusion that they were not mature. So they cannot have ascended the river for the purpose of spawning and consequently should be looked upon as stray individuals from the autumn and winter stock of young silvery trout in the Randers Fjord.

The bulk of the first salt water series are not spawning fish (only 4 % are marked down as mature, Tab. 6); they are young silvery trout, which enter the Randers Fjord to stay here in winter and emigrate on the arrival of spring. Not even the small number ascending the river will spawn here. Johansen & Løfting (l. c.) say of the silvery trout of the Randers Fjord: "A good deal of trout will make long stays in the Fjord, where many individuals of the youngest and not a few of the second youngest salt water series are met with at all seasons." Thus it is corroborated by recent investigations that young (immature) silvery trout advance from the sea into the Randers Fjord in considerable numbers, but another fact proved by the new investigations is that the young sea trout occurring in the Fjord are not equally distributed over all months of the year, but will be met with mostly in autumn and the winter months.

The second salt water series (the individuals are marked down as circles in Fig. 4 a and b) has spent a period in the sea, the duration of which is more than one year but less than two years. Individuals of this series begin to appear in the Fjord in July, in August 3 specimens were caught, in September a good deal of them occur, and the same may be said of the rest of the autumn and the whole winter; in March their number decreases considerably, and in April only one specimen was observed.

As regards the occurrence in the Fjord, then, the first and the second salt water series have many features in common, only that the latter seems to begin its ascent one month before the former. But apart from the parallelisms of time as regards ascent and descent there is, from a biological point of view, a considerable difference between the two series: quite an insignificant number (7 %) of the first salt water series make their way as far as to the river

whereas no less than 25 % of the second are caught here; the males of the first salt water series outweigh the females in number, the opposite state of things appears in the second series where we find 38 females as against 23 males. Finally there is an outspoken distinction between the stages of maturity: within the first salt water series only 4 %, within the second 25 % of the individuals were mature.

Both mature (coloured) and immature (silvery) trout of the second salt water series were caught during the whole of the period from July to March. So we may take it for granted that at any rate part of the immature fish will not reach the stage of maturity later on during the period but will descend once more in spring without having spawned. In a biological respect we should therefore distinguish between two groups of the second salt water series: one group which, like the first salt water series, only lives in the Fjord (and perhaps the lower part of the river) in winter, and another, which enters the Gudenaå through the Randers Fjord for the purpose of spawning. The second salt water series is the youngest series that shows a fairly considerable number of spawning individuals. This agrees well with the fact that in February—March we meet with some kelts of this series whereas no kelts of the first salt water series have been observed.

The third salt water series (marked down in the Fig. as points surrounded with circles) has spent between two and three years in the sea before the ascent. The first appearance of this series in the Fjord takes place already in May and June (one and two specimens, resp.); in July and August its representatives are still few in number. The largest quantities are caught in the Fjord in September and October; smaller quantities are taken in January—March. In the river there is a somewhat different distribution, the largest numbers being taken here already in June. This fact seems to indicate that the trout of this series that ascend during the first part of the season are mere passers-through in the Fjord; their ascent is in a typical way directed by the purpose of spawning. Most of the trout caught in the months of May and June are silvery trout, both when taken in the Fjord and in the river (in the Fjord 4 silvery trout — 0 coloured, in the river 12 silvery trout — 1 coloured); in August, however, the coloured fish are in the majority (in the Fjord 6 silvery — 10 coloured trout, in the river 1 silvery — 10 coloured trout). In December—March no indivi-

duals of this series were caught in the river, the catches in the Fjord during the same months being 10 silvery trout and 1 coloured specimen. Apparently a great number of individuals of this series ascend the river early in summer as silvery trout and put on their spawning dress later in the season. Another group (caught as coloured trout in the Fjord in August—October) has either entered the Fjord as coloured fish during these months, or it has entered the Fjord early in summer but has, unlike the former group, remained in the Fjord for some months before its individuals — as coloured fish — began the proper spawning migration. It seems, however, as if the third salt water series includes still another biological group, viz. a group including the silvery trout taken in the Fjord during the winter half year and perhaps some of the silvery fish that were caught in summer and autumn. Apparently this third group consists of trout, which, like the first and part of the second salt water series, enters the Randers Fjord only to spend the winter here and emigrates once more in early spring without having spawned.

Only a few individuals of the fourth and of older series were examined, so that we cannot make definite conclusions as to the biological conditions of these series. As was the case with the third salt water series the females are in the majority, and there is a comparatively large number of mature fish. The time of ascent appears to coincide with that of the third salt water series.

In connexion with the ascent of the sea trout into the Gudenaa and the Randers Fjord it should briefly be stated in this place how many of the trout ascending have spawned once or several times earlier. During the maturation of the reproductive organs a decomposition takes place in the edge of the scale, so that a mark, the spawning mark, is formed, showing that a spawning has taken place. As mentioned above only quite an insignificant number of the first salt water series will spawn; larger quantities of spawning fish do not appear until in the second salt water series; so it is not until the third salt water series appears that we may

expect to find individuals that have spawned earlier. The table below states the number of trout of these older salt water series, the scales of which exhibit one or several spawning marks corresponding to the number of previous spawnings with subsequent stay in the sea and ascent from the sea.

Out of 122 individuals belonging to these age groups 26 specimens or 21 % had spawned before, 4 specimens twice and the rest once. Johansen & Løfting state that out of 38 adult individuals between 46 and 100 cm. 5 individuals (13 %) had spawned before, one of them exhibiting two or three spawning marks. The numbers of previous spawners given here should, however, be considered minimum figures because the spawning mark is not always distinct in all scales of a fish; so there is a possibility that the spawning mark has escaped observation or has been totally invisible in the scale samples of some few of the fish examined.

b. Investigations based on statistics of number and weight of sea trout caught in the months of January—October.

The statistic material used in this chapter originates partly from the official statistics of the Board of Fisheries, partly from information forwarded to the Biological Station by fishmongers in Randers. In the official statistics of the Board of Fisheries the lower part of the Gudenaa (below Tange) and the Randers Fjord are dealt with collectively, whereas the material received from Randers was specified in a way as to form the basis of a distinction between the catches in the Fjord and the catches in the Gudenaa proper (between Randers and Tange). In November—December the coloured trout are protected; accordingly the fishery of these months works only part of the stock, so that the statistics of these months are not representative of the stock of the river and the Fjord.

The material received from Randers does not give the complete yield of the fishery in the Randers Fjord and the Gudenaa although it covers a con-

Age	.2 + — .3			.3 + — .4			.4 + — .5			.5 + — .6			Total		
Sex	♂	♀	♂ + ♀ ¹⁾	♂	♀	♂ + ♀ ¹⁾	♂	♀	♂ + ♀ ¹⁾	♂	♀	♂ + ♀	♂	♀	♂ + ♀ ¹⁾
No spawning marks	13	45	64	7	13	25	1	6	7	0	0	0	21	54	96
one spawning mark	1	3	4	6	4	10	4	4	8	0	0	0	11	11	22
two spawning marks	0	0	0	1	0	1	0	1	2	0	1	1	1	3	4

¹⁾ Sex determinations were not carried out in all cases.

Tab. 7 a. Catches of sea trout in kgs. in the Randers Fjord and in the lower part of the river Gudenaa.

Year ...	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	Mean
Jan. ...	..	150	..	200	159	171	..	58	34	204	74	56	171	83	95	58	176	102
Feb. ...	500	..	..	..	85	106	..	63	101	188	54	..	97	52	41	159	221	92
Mar. ...	200	200	..	..	180	48	..	13	86	34	128	100	171	134	71	343	260	118
Apr. ...	50	540	..	..	..	..	318	43	10	6	40	156	6	94	11	60	43	78
May ..	50	150	400	..	669	100	182	143	156	47	31	20	2	5	12	49	22	114
June ..	300	250	400	336	105	215	122	123	177	91	32	31	27	33	45	28	23	138
July...	275	250	150	1147	800	564	410	450	160	c.150	104	90	85	58	62	12	28	282
Aug. ...	320	300	200	1145	1000	479	311	375	113	c.100	205	85	133	170	84	202	92	313
Sep....	860	1000	400	455	1200	600	1209	995	220	c.150	492	499	703	330	792	531	178	607
Oct....	400	600	100	1500	..	956	1218	500	287	c.350	700	660	1414	1358	1316	787	447	741
Nov. ...	42	75	60	..	..	..	..	75	14	c. 50	53	66	57	62	177	55	44	..
Dec....	..	..	..	..	..	..	23	..	..	..	..	30	41	82	40	3	39	..
Total..	2997	3515	1710	4783	4798	3239	3793	2838	1358	1370	1913	1793	2907	2461	2746	2287	1573	..

Tab. 7b. Catches of salmon in kgs. in the Randers Fjord and in the lower part of the river Gudenaa.

Year	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934
Jan.	..	..	..	..	..	168	29	23	..	..	..	..	..	..	..	..	..
Feb.	50	..	..	..	..	248	25	42	..	..	..	..	..	..	..	..	13
Mar.	150	100	100	75	500	503	104	107	10	..	1	..	..	..	..	..	..
Apr.	100	250	100	275	410	742	229	142	9	..	13	..	..	..	..	..	..
May	300	50	..	327	195	742	160	58	..	..	92	..	..	..	..	..	..
June	250	..	..	200	423	305	117	88	..	32	10	..	..	..	..	..	..
July.....	75	..	70	25	800	602	43	..	17	..	..	..	..	..	5	..	..
Aug.	50	65	..	..	55	135	..	..	11	..	..	..	..	..	7	..	..
Sep.....	..	..	..	..	..	28	..	..	..	..	..	..	..	..	..	7	..
Oct.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Nov.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Dec.	..	..	..	10	..	..	..	..	..	..	..	..	..	..	..	..	..
Total ...	975	465	270	912	2383	3473	707	460	47	32	116	..	..	..	12	7	13

siderable part of it. From the years 1927—34 it includes 15 778 kgs., the total catches in the Gudenaa and the Randers Fjord amounting to 17 050 kgs. according to the statistics of the Board of Fisheries.

Basing on the statistics of the Board of Fisheries Table 7 a gives the catches in kgs. of sea trout in the Randers Fjord and the lower part of the Gudenaa in various months of the years 1918—34. The last

catches of November—December are not stated because, as mentioned above, they are not representative of the stock on account of the partial protection. The survey in the subjoined table is also based on the statistics of the Board of Fisheries; it gives the individual weights in the various months of the years 1933 and 1934 (number of individuals in brackets):

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Okt.
1933	1.3 (45)	1.0 (161)	1.2 (279)	1.5 (41)	1.4 (36)	1.8 (16)	1.8 (7)	2.2 (92)	2.0 (262)	2.4 (324)
1934	1.0 (169)	0.9 (247)	0.9 (293)	1.0 (43)	2.7 (8)	2.6 (9)	1.7 (16)	1.8 (52)	2.2 (80)	2.3 (194)

column of the Table gives the average catch per month of all years collectively. It appears from the figures that the catches, calculated in kgs., were light during the first months of the year, especially in April (78 kgs.). From this month there is a steady rise of the catches until August, followed by a very rapid rise in September and a somewhat slower rise in October. The heaviest average catch per month (741 kgs.) occurs in October. The monthly average

It is noted that many, but small individuals are caught in January—March, few but rather big individuals in April—July, and many big individuals in August—October. It further appears from the table that there is a slight decrease of the average weight late in summer, followed by another rise in the early autumn. These monthly variations of the weight will be submitted to a closer investigation in the following discussion of the statistics forwarded

Tab. 8 a. Yield of fishery (No. and kgs.) and monthly mean weights of sea trout caught in the Randers Fjord

Year	1927			1928			1929			1930			1931		
	No.	kgs.	kgs./ind.	No.	kgs.	kgs./ind.	No.	kgs.	kgs./ind.	No.	kgs.	kgs./ind.	No.	kgs.	kgs./ind.
Jan.	30	35	1.2	5	10	2.0	14	31	2.2	188	255	1.4	27	53	2.0
Feb.	22	27	1.2	68	69	1.0	6	4	0.7	133	148	1.1	58	92	1.6
Mar.	26	26	1.0	161	164	1.0	171	161	0.9	292	366	1.3	52	70	1.3
Apr.	4	4.7	1.2	70	77	1.1	122	167	1.4	58	111	1.9	56	101	1.8
May	2	11	5.5	38	26	0.7	13	21	1.6	13	40	3.1	15	25	1.7
June	7	25	3.6	5	4.3	0.9	2	9.6	4.8	2	23	1.2	7	14	2.0
July	6	27	4.5	13	42	3.2	1	2.9	2.9	16	28	1.8	13	29	2.2
Aug.	..	..	..	26	63	2.4	42	91	2.2	26	59	2.3	28	64	2.3
Sep.	20	52	2.6	125	301	2.4	192	405	2.1	146	435	3.0	175	550	3.2
Oct.	88	248	2.8	185	523	2.8	270	614	2.3	156	424	2.7	190	605	3.2
Nov.	19	17	0.9	39	49	1.3	99	81	0.8	30	60	2.0	39	38	1.0
Dec.	13	15	1.2	24	20	0.8	55	38	0.7	21	42	2.0	16	22	1.4
Total	237	488	2.1	759	1348	1.8	987	1626	1.6	1081	2070	1.9	676	1563	2.3

Tab. 8 b. Yield of fishery (No. and kgs.) and monthly mean weights of sea trout caught in the lower part of the Gudena

Year	1927			1928			1929			1930			1931		
	No.	kgs.	kgs./ind.	No.	kgs.	kgs./ind.	No.	kgs.	kgs./ind.	No.	kgs.	kgs./ind.	No.	kgs.	kgs./ind.
Jan.	38	109	2.9	21	68	3.2	12	26	2.2	16	46	2.9	2	7.4	3.7
Feb.	8	16	2.0	5	10	2.0	..	..	..	3	4.5	1.5	6	14	2.3
Mar.	3	8	2.7	50	66	1.3	6	25	4.2	2	2.6	1.3	..	..	..
Apr.	1	1.3	1.3	9	10	1.1	3	5	1.7	4	10	2.5	5	12	2.4
May	10	28	2.8	11	10	0.9	..	..	..	..	..	..	..	..	..
June	16	67	4.2	15	52	3.5	6	29	4.8	4	23	5.8	9	25	2.8
July	21	88	4.2	22	63	2.9	11	42	3.8	18	63	3.5	13	29	2.2
Aug.	7	34	4.9	57	151	2.6	14	38	2.7	25	75	3.0	40	118	2.9
Sep.	32	98	3.1	75	163	2.2	29	82	2.8	53	148	2.8	45	182	4.0
Oct.	51	265	5.2	67	176	2.6	94	226	2.4	108	470	4.4	65	352	5.4
Nov.	..	..	..	3	3.3	1.1	..	..	..	..	..	..	..	..	..
Dec.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Total	187	714	3.8	335	772	2.3	175	473	2.7	233	842	3.6	185	739	4.0

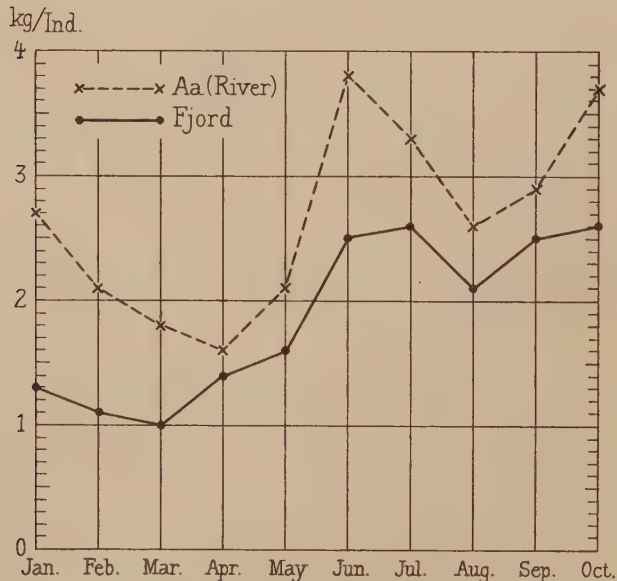


Fig. 5. Monthly variations of the average weight of sea trout caught in the Randers Fjord and the Gudena proper (the years 1927—34).

from Randers, which enable us to distinguish between the catches of the river and those of the Fjord.

The Randers material has been worked up in Table 8 a and b, 8 a giving the trout caught in the Randers Fjord (from Randers to Udbyhøj) and 8 b the trout caught in the Gudena proper below Tange (from Stevnstrup to Tange). The trout were weighed at the fishmongers', who have forwarded the material; on the whole the weighings allow a limit of abt. 25 g.

The individual average weight is in the Randers Fjord 1.76 kg. (6232 ind.) and in the Gudena 3.05 kg. (1552 ind.) or nearly twice as high in the Gudena as in the Randers Fjord. This considerable difference makes it clear that the trout fished for in the two areas do not show the same composition. In other words the Randers Fjord is not only a place of passing to the trout during its ascent to the spawning places of the Gudena; it is also the living place of a special stock of trout, the individuals of which are not migrating in order to spawn but enter the Ran-

rd (from Randers and downwards) in the years 1927—1934. (After material received from fishmongers in Randers).

	1932		1933			1934			All years		Mean for all years		
	kgs.	kgs./ind.	No.	kgs.	kgs./ind.	No.	kgs.	kgs./ind.	No.	kgs.	No.	kgs.	kgs./ind.
6	91	1.6	27	39	1.4	129	115	0.9	476	629	60	79	1.3
5	51	1.5	93	116	1.2	194	171	0.9	609	678	76	85	1.1
1	82	1.2	303	276	0.9	202	169	0.8	1278	1314	160	162	1.0
2	94	1.5	35	49	1.4	79	73	0.9	486	677	61	85	1.4
1	0.9	0.9	21	32	1.5	7	18	2.6	110	174	14	22	1.6
6	19	3.2	..	..	..	8	17	2.1	37	91	5	12	2.5
8	32	4.0	4	6.5	1.6	12	21	1.8	73	189	9	24	2.6
3	38	2.9	40	67	1.7	37	68	1.8	212	450	27	56	2.1
	282	3.1	200	401	2.0	105	215	2.0	1054	2641	132	330	2.5
0	361	3.0	216	471	2.2	135	294	2.2	1360	3540	170	443	2.6
7	73	1.3	25	29	1.2	18	28	1.6	326	375	41	47	1.2
6	63	1.1	3	3	1.0	23	29	1.3	211	232	26	29	1.1
3	1187	2.1	967	1490	1.5	949	1218	1.3	6232	10990	779	1374	1.76

r Gudena (from Stevnstrup to Tange) in the years 1927—1934. (After material received from fishmongers in Randers).

	1932		1933			1934			All years		Mean of all years		
	kgs.	kgs./ind.	No.	kgs.	kgs./ind.	No.	kgs.	kgs./ind.	No.	kgs.	No.	kgs.	kgs./ind.
0	25	2.8	..	..	..	25	47	1.9	123	328	15	41	2.7
7	18	2.6	..	..	..	5	8	1.6	34	71	4	9	2.1
	..	..	..	..	..	6	19	3.2	67	121	8	15	1.8
4	6	1.5	..	..	..	3	3	1.0	29	47	4	6	1.6
4	11.5	2.9	3	7.9	2.6	1	4	4.0	29	61	4	8	2.1
	26	6.5	8	15	1.9	2	7.7	3.9	64	245	8	31	3.8
8	30	3.8	4	7	1.8	3	5.2	1.7	100	327	13	41	3.3
8	34	2.6	52	110	2.1	15	27	1.8	223	587	28	73	2.6
3	98	4.3	57	127	2.2	11	37	3.4	325	935	41	117	2.9
	177	4.3	69	192	2.8	50	133	2.7	545	1991	68	249	3.7
3	3	1.0	6	16	2.7	1	3.1	3.1	13	25	2	3	1.9
	..	..	..	..	..	..	..	..	..	..	..	..	..
3	429	3.7	199	475	2.4	122	294	2.4	1552	4738	194	592	3.05

ders Fjord for other purposes. This is in good accord with the results of the scale analyses: the young silvery trout of the first and second salt water series live in the Fjord in autumn and winter, a fact which causes the individual weight to be considerably lower here than in the river.

Fig. 5 represents the variations of the individual weights month by month, partly in the Randers Fjord, partly in the Gudena between Stevnstrup and Tange. Here, too, the months of November and December were not included on account of the partial protection of the trout during this period. It appears distinctly from the figure that all the year round the individual weight is somewhat lower in the Fjord than in the river. The greatest difference in weight is met with during the winter months, the time, as mentioned, when the large stock of silvery trout of the first salt water series is found in the Fjord but not in the river. In April—May the difference of weight is very small, which agrees well with the fact that the small silvery trout have now left the river.

Before dealing with the monthly variations of the individual weight it would be expedient to examine the variation in the numbers of trout caught in the Randers Fjord and the Gudena throughout the year. Fig. 6 represents the numbers of individuals (average figures of the whole series of years considered) caught in the various months of the year. Like the graphs showing the individual weights the graphs of this figure are based on the material from Randers; it should be noted that the material does not include the months of November—December. As regards the Randers Fjord the graph of the numbers exhibits two distinct summits: one in spring and another in autumn, separated by a very steep decline in summer and a less pronounced decline in winter. The spring maximum is characterized by 160 specimens in March; during the following months the numbers fall to 5 and 9 specimens in June and July. After that the numbers increase once more until the autumn maximum is reached with 170 specimens in October. The winter minimum, 60 specimens, occurs in January.

If now, for comparisons sake, we look at the graph representing the monthly average number in the river, we find quite another course of the graph. Unlike the graph of the Fjord it has only one summit, the maximum occurring in October (and thus coinciding with the autumn maximum of the Fjord) and a very long minimum in the months of January—May (June). The early spring maximum of the Fjord has no equivalent in the river. The difference of the

The cause of this rise is a double one: the young, light sea trout have emigrated to the sea and in the same months the larger trout begin their ascent towards the spawning places of the river. It appears from Fig. 4 that a number of large trout of the 3rd—6th salt water series appear both in the Fjord and the river in the very months of May and June. Coincidentally with the rise of the individual weight there is a most rapid falling away of the numbers

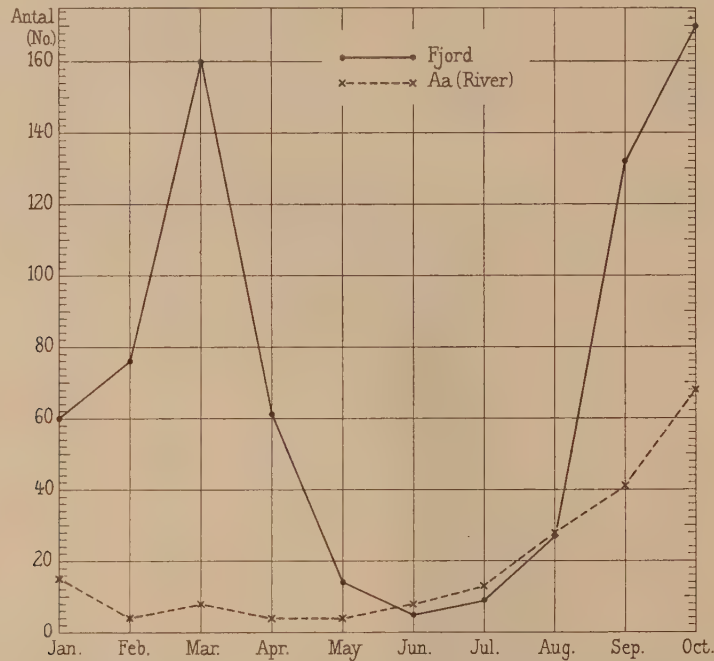


Fig. 6. Monthly variations of the numbers of sea trout caught in the Randers Fjord and the Gudena River (the years 1927—34).

two graphs is another expression of the difference between the stocks of trout in the river and the Fjord: the abundant stock of young silvery trout found in the Fjord in winter and early spring does not ascend the river. For the months of May—October the graphs of numbers are rather uniform, both showing a steady if not equally steep rise. At this time much the same stock is found within both areas, viz. older, large sea trout on their way to the spawning places.

The graphs of the individual weight, as mentioned above, are characterized by the weight minimum in early spring (March: 1.0 kg. in the Fjord, April: 1.6 kg. in the river). During the following months the individual weight rises very rapidly until it attains its maximum of 3.8 kgs. in the river in June and of 2.6 kgs. in the Fjord in July.

of individuals in the Fjord and an insignificant one in the river (see Fig. 6). In the Fjord the rise of the individual weight cannot by far make up for the declining number of individuals, and the average catch per month falls from 162 kgs. in March to only 12 kgs. in June. Also the river yields the lightest catches in spring and early summer: 6 kgs. in April and 8 kgs. in May. According to the official statistics, which include the catches of both river and Fjord, the lightest catch per month (78 kgs.) occurs in April, the very time when the young silvery trout and the kelts have left the area, and the old spawning trout have not yet commenced to ascend (see Fig. 4).

Accordingly, the average weight reaches a maximum in June—July. In August there is another fall, in the river to 2.6 kgs., in the Fjord to 2.1 kgs.; but in September and October it rises again to nearly

the same heights as in June and July. The August minimum is more distinct in the river than in the Fjord. This observation to a certain degree corresponds with the results of the scale analyses, for it appears from Table 5 that in August individuals of the oldest salt water series (the heaviest specimens) were taken neither in the river nor in the Fjord, whereas they were caught both during the previous and the subsequent months. The observation is further corroborated by the measurements and weighings carried out at the Friesenvold fish wear in the years 1899—1914. According to Johansen & Løfting (l. c.) the average lengths and weights of these trout in the months of May—October were as follows:

Month	May	June	July	Aug.	Sep.	Oct.
Average length in cm.	69	70	63	62	70	71
Average weights in kgs.	3.28	3.75	2.71	2.46	3.88	3.87

These investigations establish the occurrence of a distinct minimum of both weight and length in July and August (more especially in August). The only explanation of this minimum in the middle of summer is obviously that to some degree the old spawning trout will suspend their ascent during the period when the water is at its warmest.

The principal results of these investigations concerning the ascent of the sea trout may be summed up in the following way:

The fish ascending from the sea include two biological groups:

- A. Trout ascending with no purpose of spawning. Most of these trout belong to the first salt water series, a smaller number to the second salt water series, and most probably there is a few still older trout among them. The ascent commences late in summer and in the beginning of the autumn, the second salt water series starting earlier than the first. The descent takes place in early spring. Most individuals of this group stay in the Fjord, only a few ones ascending the river.
- B. Trout ascending for the purpose of spawning. This group principally consists of old trout of the third and older series together with a number of individuals of the second and quite a few specimens of the first salt water series. The ascent begins in the spring months at a time when a considerable part of them are still silvery trout. The old ones

will generally ascend earlier than the young. The descent of the kelts takes place early in spring, especially in March.

The condition of the Gudena sea trout.

The condition of the sea trout as well as the salmon is subject to great variations. Individuals coming directly from the sea are very fat and consequently very heavy for their length. Also the mature individuals, which have gradually transferred part of their stock of nourishment to the maturing reproductive organs, are very heavy. The kelts, however, which have just spawned, are lean and thin and very light for their length. In other words the proportion of the weight of a fish to its length is an expression of its condition. This expression I have put down in

the formula $k = \frac{100 g}{l^3}$, where g denotes the weight

in grs. and l the length in cm. The formula is used here instead of the formula agreed upon in the international meeting of salmon experts in Gdynia ($k = \frac{84.3 g}{l^3}$), because by means of the former it is possible to compare the results with the investigations of Johansen & Løfting in the Gudena during the years down to 1919.

In the various biological groups of sea trout I have found the following coefficients of condition:

Young trout on the smolt stage.....	$k = 0.87$	(14 ind.)
Silvery trout (young as well as old ones)	$k = 1.10$	(157 —)
Mature trout	$k = 1.23$	(50 —)
Kelts	$k = 0.82$	(14 —)

Kelts and smolts show the poorest condition, mature trout the best one, while the silvery trout take up an intermediate position. The figures agree well with Johansen's & Løfting's figures from the years 1916—18: 1.19 for spawning trout and 0.82 for kelts. Johansen & Løfting further give the coefficient of condition for silvery trout caught in the Randers Fjord in January—February 1916. Nearly $\frac{2}{3}$ of these silvery trout (a total of 59) belong to the first, abt. $\frac{1}{3}$ to the second and 3 individuals to the third salt water series. The coefficient of these 59 individuals was 1.07, i. e. much the same as that of the silvery trout after 1920 (1.10).

Fig. 7 gives the varying values of k within the biological groups: silvery trout, mature trout, and

kelts. The smallest variations are found in the smolts, ranging only between 0.82 and 0.98, and in the kelts, ranging between 0.5 and 1.0. The small variations of these groups must no doubt be ascribed to the fact that they are only caught at a certain limited time of the year, the smolts in April—May and the kelts in February—March. A greater variation (0.9—1.7) is found in the mature trout, which goes well with the circumstance that this group is being caught during a longer period (June—February),

For the various age groups of mature trout the condition is fairly the same:

1. salt water series	.....	.0+—.1	1.24 (4 ind.)
2. —	.....	.1+—.2	1.25 (12 —)
3. —	.....	.2+—.3	1.25 (20 —)
4. —	.....	.3+—.4	1.22 (7 —)
older —	.....	.4+—.6	1.16 (7 —)

As far as the silvery trout are concerned Fig. 7 shows a somewhat varying condition; k ranges

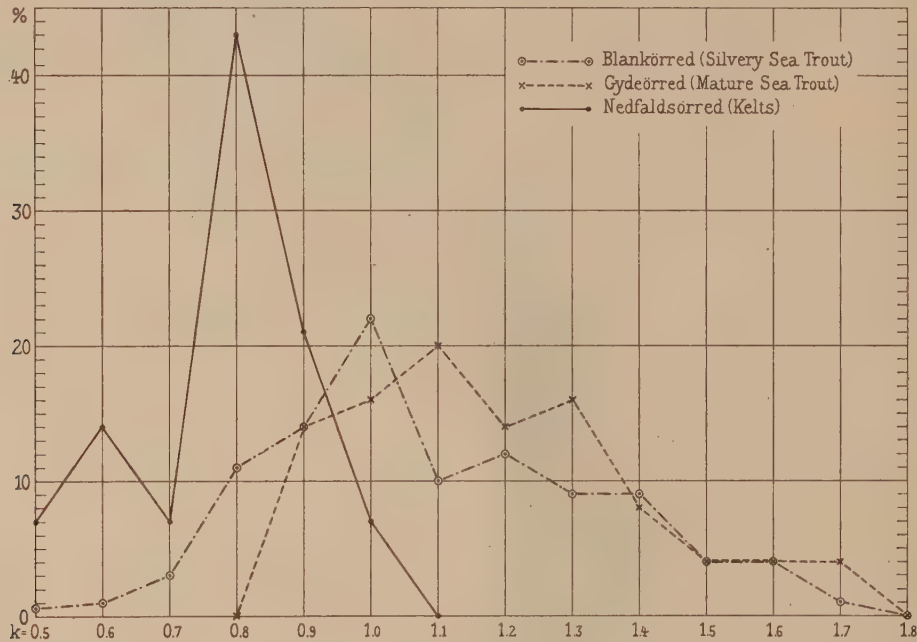


Fig. 7. Variations in the size of the coefficient of nutrition in silvery trout, mature trout, and kelts. For each group of trout the graphs state how many per cent. of the individuals examined are found within the different values of k .

thus including trout of a rather different degree of maturity, and as a matter of fact a calculation of k for mature trout gives rather different figures within the various months:

June—August.....	1.30 (7 Ind.)
September.....	1.28 (13 —)
October.....	1.25 (19 —)
November—February.....	1.13 (11 —)

In other words, a considerable falling off of the condition takes place from late in summer and autumn till late in winter. This is a natural consequence of the trout spending rather large amounts of energy during their ascent, at the same time feeding scantily.

between 0.5 and 1.7, the graph is rather flat and the maximum at the average value not very high. This is due to the heterogeneous biological composition of the group, which consists partly of young, partly of old silvery trout, of silvery trout ascending but not going to spawn, and of others, which are on their way to the spawning places but have not yet put on their coloured spawning dress; finally should be added that silvery trout are caught nearly all the year round.

In silvery trout of different age groups k varies as follows:

1. salt water series	.....	.0+—.1	1.02 (54 ind.)
2. —	.....	.1+—.2	1.12 (49 —)
3. —	.....	.2+—.3	1.31 (33 —)
4. —	.....	.3+—.4	1.32 (12 —)
5. —	.....	.4+—.5	1.40 (9 —)

It is noted that k is lower in the youngest silvery trout and higher in the older ones. For the two youngest salt water series $k = 1.06$, but for the three oldest ones it is 1.31, a rather considerable difference. The longer the sea trout has lived in the sea before the ascent, having the benefit of its nutritious food, the better its condition.

Within the same series the season of the year will cause some variation in the condition. Only in the first salt water series such a variation has not been established, nearly all individuals of this series being caught in winter. The subjoined synopsis gives the values of k in individuals of this series, caught in different months:

August-October	0.99 (4 ind.)
December	1.08 (8 —)
January	0.99 (15 —)
February	1.04 (16 —)
March	1.01 (11 —)

Here the value of k is fairly the same throughout the period of investigation.

As to the older series, however, the captures of which are distributed over several months, there is a marked difference in the value of k between the trout caught in the summer half-year and those caught in the winter half-year. The second salt water series was found to have the following values of k :

April—October	1.25 (18 ind.)
November—March	1.04 (31 —)

and trout of the third and older salt water series:

April—October	1.32 (42 ind.)
November—March	1.17 (12 —)

These figures indicate an obvious difference of condition according to whether the individuals in question were caught during the summer or the winter half-year, the condition being better in summer and early autumn and poorer in winter and the beginning of the spring. So the condition of the older silvery trout varies seasonally in much the same way as that of the spawning trout, which is easily explained for by the circumstance that at any rate part of these silvery trout ascend for the purpose of spawning. The decline from summer to winter may of course partly be due to the less favourable feeding conditions of winter; but ap-

parently it is to some degree brought about by the fact that the high-fed individuals ascend at an earlier season than those showing a poorer condition. By way of example may be stated that 26 individuals of the second and older salt water series, caught in the beginning of summer (May—July), had a coefficient of 1.35, while 24 individuals, caught late in summer, only had a coefficient of 1.26.

The results of the investigations on the condition of the sea trout may be summed up as follows:

1. Smolts and kelts have a low coefficient of condition (0.82 and 0.87, respectively) and the mature trout have a high one (1.23), while that of the silvery trout takes up an intermediate position (1.10).
2. The young ascending silvery trout show a poorer condition than the old ones.
3. The condition is better in summer than in winter.
4. Of the sea trout ascending early and late in the season the former show the better condition.
5. The present condition of the sea trout is equal to that of the years before 1920.

On the means of restoring the stock of salmon and sea trout in the Randers Fjord and the Gudenaa.

In one of the preceding chapters (see p. 10 ff.) attention has been drawn to the rapid decrease of the salmon and trout fishery in the Gudenaa and the Randers Fjord during these 10—15 years. In the course of this period the salmon has completely disappeared from the area and the yield of the sea trout fishery has fallen to about half its former size. It has been demonstrated that the principal cause of the decrease is the weir of the Tange Generating Station, which bars the access of the salmon and partly of the sea trout to the spawning places. Suggestions were advanced to the effect that the wheel fishery in the Randers Fjord and the increased pound net fishery on the eastern coasts of Jutland have a share in the decrease, a share, however, which is much inferior to that of the Tange Station.

On the other hand the biological investigations have shown that the sea trout is still able to live and thrive in the Randers Fjord and the lower part of the river Gudenaa and its tributaries (the Nørreaa); the growth of the sea trout is as rapid as earlier, it has maintained its former condition, and it continues to spawn in suitable places below Tange. So

Tab. 9. No. of fry and $\frac{1}{2}$ -yearlings by thousands liberated in the river Gudenaa with its tributaries and in the river Alling Aa (falling in the Grund Fjord) in the years 1920—34. After the Danish Fiskeri-Beretning.

Year	Age of the output	Gudenaa above Tange	Gudenaa below Tange	Nørreaa	Alling Aa	Total
1920	tiny	145 ²⁾	..	20 ¹⁾	..	165
1921	—	400 ⁴⁾	..	..	100 ³⁾	500
—	$\frac{1}{2}$ -year	..	30 ⁴⁾	..	..	30
1922	tiny	400 ⁴⁾	..	15 ¹⁾	400 ³⁾	815
—	$\frac{1}{2}$ -year	30 ⁴⁾	..	..	..	30
1923	tiny	400 ⁴⁾	..	..	230 ³⁾	630
—	$\frac{1}{2}$ -year	15 ⁴⁾	..	..	..	15
1924	tiny	355 ⁴⁾	..	..	172 ³⁾	527
—	$\frac{1}{2}$ -year	18 ⁴⁾	..	..	..	18
1925	tiny	475 ⁴⁾	..	10 ¹⁾	160 ³⁾	645
1926	—	382 ⁴⁾	..	20 ¹⁾	179 ³⁾	581
1927	—	243 ⁴⁾	167 ⁴⁾	300 ⁴⁾	228 ³⁾	938
1928	—	..	30 ⁴⁾	..	214 ³⁾	244
1929	—	..	230 ⁴⁾	5 ¹⁾	152 ³⁾	387
1930	—	..	230 ⁴⁾	10 ¹⁾	203 ³⁾	443
1931	—	..	64 ⁴⁾	270 ³⁾ + 14 ¹⁾	200 ³⁾	548
1932	—	..	414 ⁴⁾	200 ³⁾ + 4 ¹⁾	..	618
1933	—	..	410 ⁴⁾	230 ³⁾ + 15 ¹⁾	..	655

¹⁾ by Viborg fishermen's association, ²⁾ from Lysbro (Silkeborg), ³⁾ from Clausholm (Randers Fjords' fishermen's association), ⁴⁾ by Tange Generating Station

one should be justified in hoping that the possibilities of restoring the stock of sea trout in the Gudenaa are still present.

The salmon stock of the Gudenaa, however, has met with perfect extinction, and any attempt of retrieving the salmon fishery must therefore take the form of liberations of fry from other streams (for instance the large rivers of West Jutland).

Before discussing the possibilities of restoring the stocks of salmon and trout it will be advisable to examine what has hitherto been done in this respect and the result of such undertaking.

Liberations of the fry of sea trout and salmon in the Gudenaa and its tributaries have been carried out through a long series of years. The extent of the outputs of the years 1902—15 (in 1916—19 no liberations took place) is stated by Johansen & Løfting (l. c. p. 141). An average of 150 000 specimens of tiny salmon fry and 50 000 $\frac{1}{2}$ -yearlings were liberated annually during the period (in most years the amounts liberated were considerably smaller). The quantities of sea trout fry liberated were somewhat larger. In the case of the salmon Johansen & Løfting found an appreciable rise of the catches to follow the liberation of fry: "as far as the statistics go, they point at favourable effects of the liberation of fry." But the authors add that "allowance should be made for the possibility that

part of the rise of yield observed in 1904—16 must be ascribed to an improvement of statistics within this period."

As mentioned no fry was put out in the years 1916—19, but from 1920 onwards fry of sea trout has been regularly liberated (s. Table 9) whereas the liberations of salmon fry has totally been abandoned. Most outputs were effected by means of tiny fry, but in the years 1921—24 small numbers (15—30 000 specimens) of $\frac{1}{2}$ -yearlings were liberated, too. The quantities of tiny fry liberated ranges between abt. 200 000 and 800 000 specimens a year. According to the terms stipulated abt. 300—500 000 specimens of these quantities were liberated by the Tange Station in the Gudenaa or its lesser tributaries, in one year also in a large tributary, the Nørreaa. The Fishermen's Association of the Randers Fjord has liberated 200—300 000 specimens a year in the Allingaa (falling in the Grundfjord), during these late years in the Nørreaa. Small quantities of 5—20 000 specimens were liberated in the upper part of the Nørreaa by the Fishermen's Association of Viborg. Both associations receive a Government grant for the liberations. As a rule the fry was liberated on or at any rate near the natural spawning areas of the sea trout. In the years before 1926 the fry put out by the Tange Station was liberated nearly exclusively above the weir of Tange; after

1927 the fry was liberated below the weir. This change in the plan of liberation was made because it has been observed that part of the young sea trout liberated above Tange did not descend to the river below Tange and from there into the sea but remained in the upper part of the Gudenaa and developed into "lake trout" in the Tange Sø or "river trout" in the Gudenaa itself. Another reason for the change of the plan is the fact that part of the descending trout perish in the turbines of Tange on their way towards the sea.

We shall now proceed to examine whether the liberations of fry during these late years have influenced the yield of the sea trout fishery in the Randers Fjord and the lower part of the Gudenaa. But for this purpose we shall first have to make clear in which year after the liberation the fry put out is able to influence the catches. The latter question is answered by means of the age determinations of sea trout caught in the commercial fishery in the Randers Fjord and the Gudenaa in the years 1920—34. The catches being stated per calendar year, I have given the age of the trout in the same way. Consequently, a trout put down in the table as being 3 years old is in fact from 3 months less to 9 months more than 3 years of age (supposing April 1st to be the date of hatching). The sea trout were weighed and their age established; they showed the following distribution as regards number and weight¹⁾:

2 years old...	29 ind.	26 kgs.	=	4 %	of the total weight
3 — — ...	67 —	96 —	=	15 %	— — — —
4 — — ...	77 —	223 —	=	35 %	— — — —
5 — — ...	34 —	163 —	=	24 %	— — — —
6 — — ...	18 —	116 —	=	18 %	— — — —
7 — — ...	4 —	23 —	=	4 %	— — — —

According to this calculation 4 % of the survivors of the fry are caught 2 years and 15 % 3 years after the liberation; in the fourth year after the liberation the effects of the liberation are at their highest: 35 % of the individuals surviving are landed in this year. In the course of the fifth, sixth, and seventh year the percentage falls again, in the seventh year only being 4 % of the individuals surviving. These percentages were used as a basis for calculating the amounts of fry that may come to influence the catches of the different years, and in Fig. 8 these figures representing the influence of the fry are com-

pared with the catch yields. Speaking generally the graphs of the figure do not tell of any effects produced by the liberations of fry. In 1921—23, when the effects could only be of small extent owing to the fact that no fry was put out in 1916—19, the catches were even exceptionally heavy, while on the other hand the catches of 1926—28 were light although the liberations of fry should have produced perceptible results. It is only during these late years, when both the liberations of fry and the catch yields have been in sinking, that we find a uniform course of the two graphs.

It would, however, be premature from this incongruity of the graphs to draw the conclusion that the liberations of fry have been of no consequence whatever. Although it does not appear from the statistics, the outputs of fry may very well have had a favourable effect on the catches, for the extent of liberation may have been too small to make up for the annual fluctuations of the fry appearing in a natural way. There is every probability that conditions are like that in the Gudenaa of all places.

In a couple of small brooks on Bornholm¹⁾; the total size of which does not exceed one of the lesser tributaries of the Gudenaa and where the normal annual catches averaged 500 kgs., the liberation of abt. 100 000 pieces of tiny fry did not influence the catches. A markedly profitable increase of the catches was not established until the numbers liberated approached half a million specimens. The yield of the catches in the Gudenaa and the Randers Fjord being about four times as large as that of these brooks and the stock being sized proportionately, the liberation of abt. half a million pieces of fry in this place would correspond fairly well to the 100 000 pieces that showed no visible outcome in the brooks of Bornholm. Accordingly, we cannot expect to find any visible outcome of the liberation of half a million specimens in the Gudenaa. Considering conditions on Bornholm we shall have to put out about 2 mill. ind. of fry in the Gudenaa before favourable effect can be established through statistics. Thus the incongruity of catch yields and liberations of fry in the Gudenaa may not be considered a proof of the valuelessness of the liberations of fry. We may only establish the fact that the liberations of fry carried out have been insufficient for making up the natural

¹⁾ Sea trout caught for hatching purposes during the time of protection are not included.

¹⁾ Erik M. Poulsen: Remarks on the Salmon and Sea trout off the Baltic Coasts of Denmark. Rapp. et Procès Verbaux, Vol. 48, 1928, p. 111.

fluctuations and for the maintenance of the stock.

The other way of remedying the disastrous effects of the Tange Station on the stock of salmon and sea trout, viz. the building of the salmon pass at Tange, has also failed to meet its ends. According to the statements of local experts none or at any rate very few of the trout ascend the pass. No salmon have got up the pass; in old times the spawning localities

there is at present any reason to discuss the means of remedying this disastrous development.

There are two ways in which to enlarge or at any rate to maintain the stock of sea trout in the Gudenaas: (A) a protection of the present population and (B) an increasing of the quantity of fry.

(A). A well-known and in many cases most effective way of protecting a population of fish is the

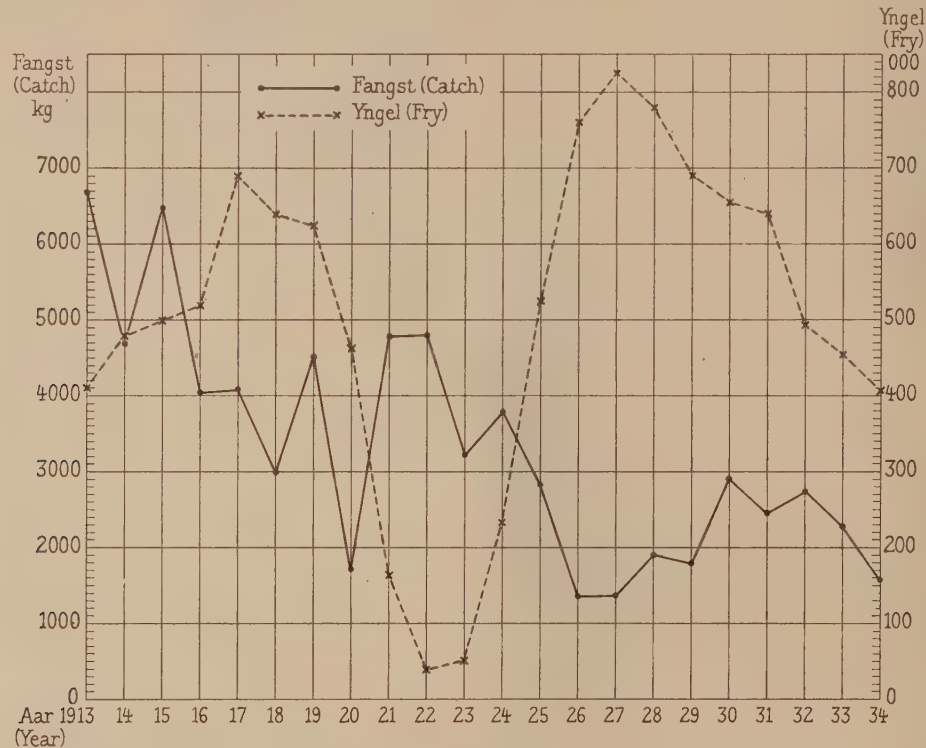


Fig. 8. Catches of sea trout in the Randers Fjord and the lower part of river Gudenaas in the years 1913—34 as compared with the quantities of liberated fry influencing the catch year in question (for closer explanation see text on p. 33).

of the salmon were situated above Tange, and the fact that the salmon has completely disappeared from the Gudenaas is a most evident proof that it has not been able to ascend the pass. During the first years after the erection of the Tange Weir the mature salmon ascended as far as Tange, but here they remained standing below the weir (in front of the lower mouth of the pass); some of the fish were caught, others died and were found to contain "diseased and putrescent roe."

During these late years, then, the salmon has completely disappeared from the Gudenaas, and the population of sea trout has fallen away rapidly. So

minimum size-limit. At present the minimum size of sea trout and salmon in the Gudenaas and the Randers Fjord is 37 cm. (this measure including the total length, from the snout to the end of the caudal fin). Now, how far does this minimum size protect the sea trout? In the first place all trout are protected during the whole of their river life down to their first emigration to the sea; furthermore the smallest individuals of the first salt water series are protected: according to the age analyses of the years 1920—34 18 % of the first salt water series are less than 37 cm. in length and are thus protected by the minimum size-limit, but they only make up a small

part of this series. Especially in winter and early spring an intense fishing of trout of the youngest salt water series is carried on, which appears partly from the samples of scales forwarded (see Fig. 4 a) partly from the statistic material sent from Randers. The scale material examined showed that the individuals of the first salt water series that were more than 37 cm. long had an average weight of 0.7 kg. In February—March the average weight of all trout caught in the Randers Fjord is 1.0 kg. or nearly the same as the mean weight of the trout of the first salt water series that have reached the size-limit, which again means that the greater part of the trout caught during these months belong to the first salt water series. The yields of catches during these months average abt. 240 individuals or 247 kgs. During the time, too, when the coloured trout are protected (November—December) these small trout are nearly the sole object of fishing (the average weight of all trout caught within this period being but 1.2 and 1.1 kg.); the annual average of these months is 67 individuals or 76 kgs. In other words the catches of the months of November—December and February—March amount to 307 individuals or 423 kgs. of the first salt water series or in number 39 % of the total annual catches of trout. Add to this a rather considerable quantity of this series caught in September—October and in January, and we may put the part of the catches that belongs to the first salt water series at abt. 50 % of the total number of individuals caught in the Randers Fjord. Seeing that the price of these small trout is much inferior to that of larger specimens (abt. 2 Kr. a kg. as against abt. 3 Kr. a kg.), it is certainly regrettable that nearly half the trout caught are of the light individuals of this group. It would be a profitable way of proceeding to let these trout escape for still another year and let the fishing begin with the second salt water series, i. e. with individuals weighing abt. 2 kgs. upwards. A protection of at any rate up to 80 % of the first salt water series might be brought about by raising the minimum size-limit from 37 to 45 cm. Such a raising of the minimum size-limit would of course to some degree diminish the profits of the fishery in the first year after the change, but the following years, when the protected trout return as larger and heavier and therefore much more valuable fish, will be an ample compensation for this loss. As mentioned the trout of the first salt water series weigh 0.7 kg. a piece; the price of this size of

trout being abt. 2 Kr. a kg. the individual value of the fish is 1.40 Kr. Individuals of the second salt water series averaging 2 kgs. in weight, and the price of this size being 3.00 Kr. a kg., the individual value will be abt. 6 Kr. or 4.3 times the value of an individual of the first salt water series. Even if abt. $\frac{1}{3}$ of the protected individuals should perish before they get back to the Randers Fjord, the protection would mean a considerably higher value of the yield of the fishery. Supposing (and this is no doubt fairly correct) that abt. 400 individuals of the first salt water series would be protected by the raising of the minimum size-limit, this would in the first instance mean a loss of 560 Kr. ($400 \times 0.7 \text{ (kg.)} \times 2.00 \text{ Kr.}$); of these 400 individuals $\frac{2}{3}$ or 266 individuals will reappear, having on their return a value of well over 1500 Kr. ($266 \times 2 \text{ (kg.)} \times 3 \text{ Kr.}$). In this case the raising of the limit would bring about a clear profit of 1 000 Kr. The trout is closely attached to its place of birth; none of the trout that were marked in the Randers Fjord or the Gudenaa have been recaptured in other streams, and so it is an obvious conclusion that nearly all trout originating from the Randers Fjord will make for this place when they are going to re-enter the fresh water.

Thus it is evident that the fishery of the Randers Fjord and the Gudenaa would profit considerably by a raising from 37 to 45 cm. of the minimum size-limit of sea trout. The advantage would of course be greater if the same minimum size were introduced all along the coast on which the sea trout of the Gudenaa is fished for (the area from Udbyhøj and southwards to Hasenøre).

Another but no doubt more difficult way of protecting the present stock of sea trout would be to restrict the use of the gears in which the young trout are chiefly caught. It was already mentioned (p. 00) that large numbers of young trout between 20 and 40 cm. in length are caught in the Randers Fjord in spring by means of wheels and in spring and early summer in pound nets on the coasts south of Udbyhøj. The wheel fishery of the Fjord is specially injurious to the smolts of 18—25 cm in length. The emigration-taking place in the months of April—May an expedient way of proceeding would be to restrict the wheel fishery in the Randers Fjord and the lower part of the Gudenaa to an essential degree during these months. Restrictions on the pound net fishery in shallow water on the coasts of the south-western Kattegat in April and June would of course mean an

additional protection and preservation of the stock of sea trout. However, the economic interests involved in this pound net fishery are no doubt too comprehensive to allow a reasonably easy introduction of restrictions for the purpose of protecting the stock of sea trout.

(B). The other means of restoring the stock of trout includes measures aiming at an increment of the quantity of fry. Within this province it is no doubt possible to do more for the sea trout of the Gudenaa than is done at present. The salmon pass at Tange, which in its present form does not allow the sea trout or salmon to reach the spawning areas above Tange, should be altered in a way as to make it fit for the ascent of these fish; its chambers should be enlarged, so that the salmon or trout ascending get space to make the spring into the next chamber. The flow of water in the pass must be intensified, too, so that the current through the pass and its lower mouth becomes strong enough to "catch" the ascending fish.

It was already mentioned that the liberations of fry are of too small an extent. 2 mill. specimens of tiny fry must be considered an adequate annual amount in the Gudenaa area; this is abt. $1\frac{1}{2}$ mill. more than the annual average amount of fry liberated during these late years. However, the liberation of such large numbers of fry should not commence until the salmon pass at Tange has been brought into order. Till then the numbers should be confined to $1-1\frac{1}{2}$ mill. pieces, which are to be distributed between the Nørreaa, Alling Aa (falling in the Grund Fjord) and the tributaries of the Gudenaa below Tange. For the purpose of giving the fry satisfactory conditions of living unnecessary pollution of the water from habitations and industrial establishments should be provided against. Finally, the mother fish should be taken from no other areas than the Gudenaa or the large streams of West Jutland, for the possibility must be kept in mind that the quality of the trout population of the Gudenaa might be reduced by a liberation of trout fry from smaller streams, where the growth rate of the trout — as is for instance the case in the brooks of Bornholm — is often much inferior to that of the trout from large streams.

Talking about the sea trout the problem turns on restoring and enlarging the population in hand, but

with the salmon matters are quite different. The salmon of the Gudenaa has been completely extinguished, and any attempt of re-establishing a salmon fishery in this place must be based upon liberations of fry from without, i. e. from the large streams of West Jutland where a population of salmon, if not a very numerous one, is still found. To begin with small experimental liberations will be adapted for the purpose. Presuming that the salmon pass at Tange is brought into good order, the fry should be liberated in the former spawning areas of the salmon in the midmost part of the Gudenaa between Tvilum and the outfall of the Borreaa; if the salmon pass is not altered a liberation of fry should be attempted in the tributary of the Gudenaa below Tange and in the Nørreaa. Most probably the best way of starting these experiments would be to liberate a small number of 1- or even 2-years old marked salmon in the localities mentioned above; the results of these marking experiments would show whether salmon from other places are able to accomodate themselves to the conditions of the Gudenaa.

As it is, the measures to be considered in the endeavours of maintaining and improving the stock of sea trout in the Randers Fjord and the Gudenaa are like the following:

1. A raising of the minimum size-limit from 37 to 45 cm.
2. Restrictions of the wheel fishery in the Randers Fjord and the lower part of the Gudenaa in April—May.
3. Restrictions of the pound net fishery on the coasts of the Kattegat southwards of Udbyhøj in April—June.
4. Improved conditions of ascent at the salmon pass of Tange.
5. Enlarged liberations of fry artificially hatched.

The rapid decay of the populations of salmon and sea trout during these 10—15 years should be brought to a stop, and the sooner a purposeful work in this respect is initiated, the greater the chances of a good result of the efforts. The Gudenaa is our greatest river and in former times had an abundance of fish. The old-established interests of the fishery should not be disregarded in consideration to a momentary industrial exploitation in such a degree as now. The

industrial establishments of recent times, which have sprung up along the Gudenaa and other streams of this country, using their flow of water partly as motive power, partly as sewerage, were in most cases called forth by states of the market that may change to the disadvantage of these establishments within some few years. The constantly increasing industrial

exploitation of our rivers makes it absolutely necessary that all parties concerned should join in the task of counter-acting the destruction of the fish populations of our rivers and of taking care that permanent interests of the fisheries are not sacrificed in consideration for the incidental gains of an industrial exploitation.

R. SPÄRCK:

Investigations on the biology of the oyster XI.

On the size and age-composition of the stock of native oyster in 1935.

In a series of papers (see Rep. Danish Biol. Stat. 31, 33, 34, and 37) the present author has shown that during a long series of years the size of the native of oyster in the Limfjord constantly decreased and that it consisted nearly exclusively of old individuals with a shell diameter of 9—12 cm. In the latest experimental dredgings of the summer of 1931 65 oysters were taken on the natural beds, all of them belonging to the original stock, but only 9 of them were less than 5 years old, and only 1 specimen belonged to the 0-group. Throughout the period from abt. 1922 to 1932 the native population of oyster in the Limfjord may be characterized as consisting of old, nearly 10-years old individuals, among which only quite a few per cent of younger individuals occurred. Also the experimental dredgings of the years 1924—31 have established that the stock has constantly been decreasing.

However, during the years after 1932 a constitutive change has taken place. During the whole of the former period, at any rate from 1919 and generally speaking even from 1914, the annual renewal of the stock has been quite insignificant, representing no more than a few per cent. of the population, whereas the renewals of 1932 and 1934 seem to represent an increase of the existing stock of several hundred per cent., so that at present the age-composition of the stock is absolutely different from what it has been during many years on end.

An experimental dredging at Nygaards Hage in the Venøbugt in Nov. 1933 yielded the following results:

Diameter of valves	Number of oysters
2—3 cm	2
3—4 -	9
4—5 -	11
5—6 -	13
6—7 -	6
7—8 -	6
8—9 -	6
9—10 -	8
10—11 -	14
11—12 -	9
12—13 -	3

As will be seen a total of 87 oysters came out. Considering that we have to do with a place to be cleared of oyster, where intense dredgings were carried out for some time, the number of oysters found is not very large. But in viewing the distribution of these 87 oysters as regards age we note that no less than 35 specimens, i. e. abt. 40 % and the sample are quite young individuals, which must be supposed to have settled down in the preceding summer, thus dating from the year 1932. Another group of 34 individuals consists of very old oyster of the kind that has prevailed in the native stock of Limfjord oyster during these 10 years. Between these two groups we have a group of 18 individuals, part of which are very old specimens of poor growth while others originate from the above mentioned insignificant annual renewal of the stock, which has taken place in the years immediately before 1932. This experimental dredging must therefore be interpreted to the effect that so large a spat fall has taken place

on Nygaards Hage in 1932 that the population of oyster has increased by abt. 40 %. Such an increase of the native stock of oyster must be characterized as very considerable. It should be remembered that the excellent spawning year 1914 did not even bring about a doubling of the stock.

An experimental dredging on Lemvig Røn in the Nissum Broad in the early spring of 1934 gave the following results:

Diameter of valves	Number of oysters
2—3 cm	2
3—4 -	3
4—5 -	5
5—6 -	11
6—7 -	6
7—8 -	10
8—9 -	10
9—10 -	9
10—11 -	12
11—12 -	5
12—13 -	0
13—14 -	1

Out of these 74 oysters, too, a considerable part, at any rate 21 %, are found to be 2 years old, thus dating from the summer of 1932. At any rate 27 specimens were distinctly old individuals, but also some of the group measuring 6—9 cm. (26 ind.) were old, slowly growing individuals, so that this locality presents quite the same picture as Nygaards Hage: a numerous representation of the 1932 year-class, a fairly numerous stock of old oysters, and comparatively few specimens of the intermediate group.

This increase of the year 1932, which was established on Lemvig Røn and Nygaards Hage, apparently did not extend to the whole of the Limfjord, but seems to be confined to a few localities, the conditions of which were particularly favourable to the spat fall. It has formerly been demonstrated (Rep. Danish Biol. Stat. 37, p. 63) that such a development might be expected to take place.

However, the summer of 1934 seems to have brought about even a more extensive spat fall, and a spat fall, too, which covered much larger areas. A dredging on a natural oyster bed off Flovlev in the Nissum Broad in November 1934 yielded few individuals of the original stock, viz. 2 specimens of respectively 8—9 and 5—6 cm. in length, but no less than 23 specimens of the 0-group, dating from the summer of 1934 and showing the following composition of size:

Diameter of valves	Number of oysters
2—3 mm	2
3—4 -	2
4—5 -	0
5—6 -	1
6—7 -	0
7—8 -	0
8—9 -	4
9—10 -	1
10—11 -	4
11—12 -	2
12—13 -	0
13—14 -	2
14—15 -	1
15—16 -	1
16—17 -	2
17—18 -	1

It will be seen from the above these 23 tiny oysters may be ranged in 3 size groups, one of 2—5 mm., one of 8—12 mm., and one of 13—18 mm., which would seem to indicate the occurrence of 3 periods of spat fall during the summer of 1934. This locality is not so favourable to the spat fall of the oyster as Nygaards Hage and Lemvig Røn where a considerable spat fall was established in 1932, and so the experimental dredging at Flovlev would seem to indicate that the spat fall of 1934 was more extensive than that of the year 1932.

This hypothesis was corroborated by continuous dredgings. At Trehuse Hage in Sallingsund, for instance, a sample of 14 oysters of the 0-group were of the following sizes:

Diameter of valves	Number of oysters
4—5 mm	3
5—6 -	0
6—7 -	0
7—8 -	0
8—9 -	0
9—10 -	1
10—11 -	1
11—12 -	1
12—13 -	2
13—14 -	2
14—15 -	1
15—16 -	0
16—17 -	1
17—18 -	1

It seen that here, too, the 0-group seems to fall into at least two groups of size, indicating 2 periods of spat fall in the summer of 1934.

There are several other instances of a considerable spat fall in the summer of 1934, occurring not only in the western broads but also in Sallingsund and

the Livø Broad where individuals of the 0-group were found for instance on Galegrund and Holme Flak in the spring of 1935. So we are able to establish that the spat fall occurring in the summer of 1934 covered large areas of the Limfjord, so that there is reason for the belief that in comparison with the stock of old oyster it amounts even to a higher percentage than the spat fall of 1932.

If no extraordinary mortality sets in we may look for a rise of the native stock of Limfjord oyster, so that in 4 or 5 years the stock of marketable oysters on the natural beds will possibly be dense enough to allow some fishing in these places. But experiences of the whole of the period from 1914 to the present day as well as of the seventies and eighties of the

last century have shown that even if such a fishery will be revived in some years, we cannot with certainty expect it to last for a long period. The population of oyster in the Limfjord, in so far as it is bound to renew itself in a natural way, will always be very fluctuating. As to the cause of the more extensive spat falls 1932 and 1934 attention should be called to the high summer temperatures of these years. At Aalborg and Odde-sund the average temperature of July was in these two years 17.4° C. and 18.7° C. and 18.9° C. and 19.5° C., respectively, thus being somewhat higher than the ordinary summer temperature of the Limfjord and approaching the temperature of abt. 18—20°, which is necessary for a fairly considerable renewal of a population of oyster.

R. SPÄRCK:

On the occurrence of *Crepidula fornicata* (L.) in the Limfjord.

It is well-known that *Crepidula fornicata*, the proper habitat of which is situated on the Atlantic coast of North America, abt. 1880 was carried to England with American oysters. In English waters it spread, and in many localities along the southern and eastern coast of England it is now very frequent and extremely hurtful to the oyster fishery (Orton 1912, Robson 1915 and 1929, Burton 1930). During these late years this noxious animal has spread from England to Holland. According to van Benthem-Jutting (1933) the first living specimens were found in the Ooster Schelde and next year it was already so common, that it might be taken by hundreds. At present it is extremely frequent in the waters of Zeeland although it is not by far so noxious here as in England. It has also been found in various other places along the Dutch coast, in most cases, however, only as empty shells. According to Adam & Leloup it has further spread to the coasts of Belgium. So far its spreading along the coast of Holland is due to the fact that oysters from the rearing localities in the Ooster Schelde are transferred to other places of the country. And moreover the larvae of this gasteropod are pelagic, so that in this way, too, it will be able to spread in Dutch waters and the southern North Sea. It is indeed a probable supposition that its spreading from South England to Holland is due to pelagic larvae.

As a matter of fact *Crepidula fornicata* has attained a high degree of frequency in the Ooster Schelde during the first years after 1930; during these very years large quantities of young oysters were transferred from Holland to the western Limfjord, and so it is no wonder that *Crepidula fornicata* was at last carried to the Limfjord. This has indeed taken

place, for in the autumn of 1934 I came across several specimens of *Crepidula fornicata* on the oyster-beds round Mullergrundene in the Nisum Broad. The frequency was not very great, but still specimens of *Crepidula fornicata* were regularly met with. In my opinion one or two individuals of this gasteropod were found on abt. 5—10 % of the oysters. Besides specimens of *C. fornicata* were often found on empty shells of oyster and *Cyprina*. On the whole the specimens found were large ones, their shells being abt. 2 cm. in length, and there is no doubt that they have been carried to the Limfjord as stationary adult individuals on the shells of the Dutch oysters.

It is a regrettable fact that this species has now also been carried to the Limfjord where it will no doubt spread in the years to come. It is to be hoped that it will not become so numerous as in the waters of South England, so that we may escape the bad consequences of its presence in Danish waters. Its noxiousness principally appears in the fact that under favourable conditions it occurs in huge quantities and sometimes covers the oyster completely, thus being a keen competitor of the latter as regards food and space. An instance of its great numerical strength is given by Orton, who states that on certain English oyster-beds where attempts have been made to exterminate the *Crepidula* no less than 20 tons have been collected a day. On the natural oyster beds of the Limfjord where even under favourable conditions the density of the oyster is not very great the *Crepidula* will hardly be of serious danger to the stock. On the artificial oyster beds of the Nisum Broad, however, where the oyster populations are much denser, there is a serious risk in a competition

for space and food. In view of these facts it is encouraging to note that the oyster population of the natural beds in a few years may be supposed to become large enough to influence the production of oyster, as will appear from the preceding little paper.

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